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3 AFFECTED ENVIRONMENT

This affected environment section was prepared with emphasis on resources that would most likely be affected by the alternatives described in Section 2. Thus, for instance, sections such as water resources and fisheries are discussed in more detail than socioeconomics and aesthetics. Where appropriate, a discussion of historical conditions is followed by a discussion of current conditions in the basin. Where the information is available, it is discussed in terms of the upper, middle, and lower basins.

This section was prepared using previous reports of the Green/Duwamish River Basin. The Corps, King County, and other organizations have conducted extensive studies of historical changes in the basin. No additional field studies were conducted in preparing this section. References cited in this chapter are presented in Section 7 of this EIS. The following key information sources are incorporated into this document by reference:

- Fuerstenberg, R.R., K. Nelson, and R. Blomquist. 1996. Ecological conditions and limitations to salmonid diversity in the Green River, Washington U.S.A. King County Surface Water Management, Bellevue, WA.

- U.S. Army Corps of Engineers. 1998. Howard Hanson Dam additional water storage project – draft feasibility study and EIS. Seattle, WA.

- U.S. Army Corps of Engineers. 1997. Green-Duwamish River ecosystem restoration general investigation. Reconnaissance report. March. Seattle District. Seattle, WA.

- U.S. Army Corps of Engineers. 1996. Howard A. Hanson Dam: Final environmental impact statement for operation and maintenance. Seattle District, Seattle, WA.

This section first presents an overview of the history of the Green/Duwamish River Basin, followed by descriptions of the environmental factors of consideration for the EIS.

3.1 Description of the Study Area History

Historically, the Green/Duwamish River Basin was nearly four times its present size because it included the White River and all of the Lake Washington drainages. The Green River flowed west to the present location of Auburn where it was joined by the White River. The combined river, then called the White River, meandered for about 12 miles to the junction with the Black River. From the junction, the combined waters flowed onward to Elliott Bay as the Duwamish River (Duwamish means “many colors” to the local Native Americans). (Corps 1997b)

The history of the Green/Duwamish River Basin from the mid-1850s until the present is one of a steady degradation of the basin’s ecosystem. In 1850, homesteads and settlements appeared in the lower river valley near the Black River, and near present-day Tukwila and Kent. By the late 1850s, a steady increase in agricultural practices began to significantly change the ecosystem of the lower valley.

Dredging of the mouth of the estuary and construction of Harbor Island by the City and Port of Seattle began in the early 1900s. Congress funded a navigation project for deepening, widening, and straightening of the estuary portion of the Duwamish River. Dredge materials were placed in the estuary during construction and maintenance of the channel. The Duwamish delta at one time had over 4,000 acres of tidal and intertidal habitat, which was important for a number of fish and wildlife species. By the mid-1940s, much of the estuary was filled; only about 1 percent of the estuary now remains.

By 1906, levees had been constructed for many miles upstream of Puget Sound to protect homesteads. In 1906, a major flood altered the course of the White River. A logjam south of Auburn redirected the course of the White River to its present alignment, no longer connecting it with the Green River. Through channelization efforts authorized by the State Legislature in 1909, this diversion was made permanent. The White River was routed through a marsh area known as the Stuck River to its present terminus, the Puyallup River. The river was renamed the Green at its intersection with the Black River (RM 11) where it then became the Duwamish. Historically, the Black River was the outlet channel of Lake Washington and the Cedar River. (Corps 1997b)

In 1912, the City of Tacoma constructed the Tacoma Diversion Dam at Palmer (RM 61.0) to create a municipal water supply. On average, the city withdraws 113 cubic feet per second (cfs) continually from the river. The diversion dam blocks over 200 miles of upstream mainstem and tributary salmonid spawning and rearing habitat. In a joint venture between the City of Tacoma and Trout Unlimited, adult steelhead are trapped below the diversion dam and trucked to the upper basin. The Muckleshoot Indian Tribe Fisheries Department plants juvenile salmonids, including coho and chinook, above Howard A. Hanson Dam (HHD).

In 1916, the Lake Washington Ship Canal and Hiram Chittenden Locks were constructed. This construction lowered the level of Lake Washington by 9 feet, thereby eliminating flows from the lake to the Black River and the Duwamish River. The Cedar River was redirected to Lake Washington, disconnecting it as well. (Corps 1997b) Construction of the canal and locks, along with the 1906 diversion, reduced the flows in the Green/Duwamish River Basin by 70 percent (diverted to other basins), with subsequent adverse effects on the anadromous fishery.

After a major flood in 1958, local and federal agencies constructed extensive levees. In 1962, HHD was built at Eagle Gorge (RM 64.5) for flood control and low-flow augmentation in the middle and lower portions of the basin during the summer months. Unlike the Tacoma Water Diversion Dam, HHD was a much larger dam with a significant flood storage and conservation pool. It eliminated the major source of spawning gravel for the little remaining spawning habitat left in the river, and also eliminated a source of woody debris that is a critical habitat feature for fish rearing in the middle Green River. With reduction of channel-forming flows and elimination of a source of coarse sediment, the river now cuts down within its existing banks. Recruitment of woody debris and river movement into new gravel-rich channels have become less possible.

Flood protection provided to bridges, roads, and homes by the dam and levees (about 90 percent of the once-extensive floodplain is no longer flooded on a regular basis) has allowed for a tripling of the population from Auburn to Tukwila. Urban growth has caused degradation of tributary streams in the basin; reduction in shade, habitat, and diversity in the mainstem river; and degradation of air and water quality. King County has purchased development rights upstream of Auburn to preserve farmland. Recently, King County has acquired easements and/or land for open space and habitat value under Waterways 2000.

The upper basin above HHD is largely in the National Forest, and the major human-created constraints on the floodplain are the Burlington Northern/Santa Fe Railroad line and the main logging haul road. Logging has been the main impact on the ecosystem, causing a steady elimination of almost all of the upper basin’s old-growth forests. Logging has reduced shade for spawning and rearing habitat, increased water temperature, and reduced woody debris recruitment. Logging practices have also increased the amount of fine sediments entering the river, while logging road construction has caused stream blockages and an increase in sedimentation.

Recent interest in reopening the Stampede Pass rail line has prompted Burlington Northern/Santa Fe Railroad to begin extensive repairs to revetments along the river to protect the rail line.

3.2 Geologic Resources

3.2.1 Geology and Soils

3.2.1.1 Historic Conditions

Historic Overview

The Green/Duwamish Basin, like other north-south trending river basins arising in the Cascade Range along Puget Sound, has been shaped by a number of geologic processes and events. The major geologic processes along the Pacific Coast are the movement of tectonic plates, volcanic activity, and glaciation.

The Puget Sound Basin was formed by tectonic plate activity. The high volcanic peaks such as Mount Rainier, Glacier Peak, and Mount Baker more recently formed atop the uplifted Cascade Range and continue to build, with numerous eruptions in modern time (Kruckeberg 1991).

Following major continent building, a series of ice advances from Canada scoured much of Washington and the northern half of the United States. The most recent glaciation left behind the deposits of gravels and compacted till material seen today in most of the soils and surface formations (Kruckeberg 1991). Vashon ice dams formed glacial lakes in many of the river valleys coming out of the Cascades and left behind layers of fine sediments.

The Green River originates in the Cascade Range south of Stampede Pass at an elevation of about 4,500 feet and flows northwest 90.5 miles to Elliott Bay (see Figure 1-1). The highest elevation in the basin is 5,750-foot Blowout Mountain on the Cascade divide. The Green/Duwamish River system flows through the North Cascades and the Puget Lowlands Ecoregions (geographic areas that are shaped by geologic processes and having distinctive climate, plant communities, and wildlife populations). Sediment deposited by rivers and streams is called alluvium. The entire floor of the Green River Valley is composed of alluvium, which ranges in thickness from tens of feet in the upper end of the valley to probably over 120 feet in the lower end of the valley (Mullineaux 1970). The alluvium is composed of coarse channel deposits and finer overbank deposits. Channel deposits are predominantly gravel and sand that are transported as bedload and deposited in bars and on the channel bottom. As the river shifts laterally, fine sediment settles out of suspension on the former gravel bars, building them up to the level of the adjacent floodplain. A typical Green River bank thus consists of a coarse lower bank covered by a layer of finer overbank sediment.

Upper Basin

The upper Green River Basin is composed of the 35 to 50 million-year-old volcanic andesites and basalts mixed with breccias and tuffs of the Cascades. These materials are quite erodible and have been weathered by glacial and alluvial activity and, to some extent, by freezing/thawing processes. Bedrock has been exposed in many areas from the scouring by glaciers. (Perkins 1993, Corps 1997a, 1997b)

Middle Basin

The Green River Gorge is cut through the sandstone and mudstone of the Puget Group, a series of soft and erodable rock units. The area downstream of the Green River Gorge represents the general location where the geologic character shifts from the rocks of the Cascades to the glacial deposits of the Puget Lowland. Landslides on the valley walls were relatively common, and relic landslides of enormous size are preserved in several locations. Such landslides have been historically common and have provided the river with much sediment. Furthermore, tributary streams, especially Newaukum Creek, pick up large amounts of sediment as they descend from the plateau above, ultimately depositing it in the river (Perkins 1993).

Lower Basin

Eventually the glacial ice retreated far enough north to allow the Duwamish Valley to reconnect with the fresh waters of Puget Sound, and the water remained fresh until the ice left the Straits of Juan de Fuca. At that time, marine water extended up the narrow Duwamish Valley all the way to present day Auburn. Since the retreat of glaciation, the Green River has been carving out a floodplain from the sedimentary, volcanic, and glacial deposits. The most significant recent geologic event was a massive landslide triggered by seismic or volcanic activity on Mt. Rainier approximately 5,000 years ago. The largest landslide is known as the Osceola mudflow, and it spilled down the White River Valley, burying the Enumclaw area and flowing into the Duwamish Valley. In some places, several hundred feet of mud were deposited. This mudflow diverted the White River northward to join the Green River. The combination of the two rivers deposited vast quantities of alluvial material to form the wide flat lower Green River Valley, which was thereafter exclusively freshwater. (Perkins 1993, Corps 1997a, 1997b)

The Green River meandered widely across the valley between what is now the present day cities of Kent and Tukwila, forming and reforming channels. The Green River was joined in Tukwila by the Black and Cedar Rivers and became the Green/Duwamish River as it meandered north to the broad marshland delta into Elliott Bay (Figure 3-1) (Dunne and Dietrich 1978).

3.2.1.2 Current Conditions

Upper Basin

The upper Green River ranges in elevation from 1,100 to 5,700 feet at the crest of the Cascade Range. The bedrock materials are generally basalts and andesites mixed with tuffs and breccias, all from volcanic origin (USSCS 1992). Recent volcanic activity at Mt. Rainier deposited ash and pumice in many areas of the upper basin. Soils in the upper basin are generally formed from the weathering of volcanic ash and pumice mixed with older glacial deposits and colluvium. Because of the relatively low elevation of the upper basin, most of the non-alpine soils have developed under coniferous forest on glacial/volcanic material. Some of the lower elevation (less than 4,500 feet) soils are quite deep (greater than 60 inches to bedrock), and most are well drained because of the underlying glacial gravels. Along the river and tributary floodplains, the soils are largely formed from alluvium. River terraces in the floodplain were built up from the deposition of material during high flows and are often well drained because of the large size of the material. On low strewn terraces and drainage ways, the soils are also formed from alluvium but are wetted at some point during most years and subject to frequent flooding. These soils can often be compacted quite severely if disturbed with equipment (USSCS 1992).

Slopes in the upper basin are highly variable but can be quite steep, especially in the upper reaches. The potential for mass wasting is high or severe on many soils where the slopes are greater than 30 percent. These soils often slump or slide in rainy periods after vegetation has been removed. Of major significance in the upper basin is the erosion and landsliding of soil after the creation of logging roads and clearing of timber. Eroded sediments frequently slide into the upper tributaries to the Green River. Roads are considered the most significant source of fine sediment production in the North Fork Green River and Sunday Creek area.

Middle Basin

Current geologic processes in the middle Green River include weathering and erosion or deposition of soil by water and landslides, uplifting caused by seismic events, and mudflows from Mt. Rainier, also caused by volcanic events. On a human time scale, continuing uplift is not noticeable. However, landslides, mudflows, and river processes are quite obvious and potentially damaging in a local context.

In the middle Green River, soils are largely formed from alluvium. These floodplain soils are subject to frequent flooding, seasonal ponding, and a high water table. Generally, riverwash and alluvium are well drained except when flooded. A number of the floodplain soils are poorly drained and classified as hydric soils because of their fine texture and seasonal flooding or ponding. Some of the depressional wetland areas have developed organic soils from deposition of plant material (USSCS 1992).

There have been significant human-induced changes to the river flow and subsequent narrowing of the floodplain and channelization of the river. These activities dramatically reduced the floodplain of the Green/Duwamish River and constrained its course similar to today's conditions. The current river is sediment-starved because HHD restricts the movement of coarse sediment from the upper basin and because of the restriction from meandering by bank protection that has reduced valley sediment input. Landslides still contribute sediment to the river, especially in the gorge area, but the sediment is often fine materials that are transported to the lower river and the estuary. (Perkins 1993, Corps 1997a, 1997b)

3.2.1.3 Lower Green/Duwamish Estuary

The soils along the lower Green/Duwamish River are not well known because extensive filling and industrial development in this area have largely covered up the native delta soils. However, it is likely that the underlying native soils are similar to soils found in other tidal deltas, such as the Nisqually River delta. It is known that the Duwamish Estuary was once a vast tidally influenced swampland and marsh area. The soils in this area were likely fine materials from alluvium mixed with organic materials from the vast amounts of plant material produced in the estuarine marshes. These soils are generally very deep, poorly drained, and subject to being compacted and destabilized when disturbed. (Perkins 1993, Corps 1997a, 1997b)

The lower Green/Duwamish River has been dredged for most of its length and saltwater now intrudes up as far as river mile (RM) 10 during summer low flows and high tides. The relocation of the Renton Sewage Plant effluent outfall from the Black River to Elliott Bay has reduced summer low flows and enabled saltwater to move further upstream in the Duwamish River (Warner and Fritz 1995). Saltwater tidal soils in this segment of the river are very fine muds and clays that form hardened banks. Some of the soils in the industrially developed Duwamish Estuary have received heavy metal, petroleum, and organic chemical contamination.

3.2.2 Fluvial Geomorphology

3.2.2.1 Historic Conditions

Fluvial geomorphology is the study of the complex interactions of riverine structures and processes that form the character and habitats of the riverine ecosystem. The seasonal pattern of floods and droughts was fundamental to the formation of the historic form of the Green River. The historic patterns of channel migration, braiding, sediment deposition, and large woody debris (LWD) recruitment were for the most part controlled by floods. However, much of the in-channel structure (i.e., bar distribution and thalweg position) tends to be formed by bankfull flows in most streams. (Perkins 1993, Corps 1997a, 1997b)

Upper Basin

The morphology of the upper river was typical of Cascade Range rivers. The headwater streams were steep, bedrock and boulder-dominated, giving way to lower gradient, alluvial streams that crossed the narrow upper valley to join the main river. This heavily forested area was sediment-rich, and the mainstem river braided and shifted across the valley floor upstream of Eagle Gorge, a steep-walled canyon dominated by bedrock benches and ledges. Below Eagle Gorge, the river gradient decreased briefly before the river entered the Green River Gorge at about RM 57. (Perkins 1993, Corps 1997a, 1997b)

Middle Basin

The river fell quickly through the 13 miles of the Green River Gorge and bedrock ledges, and large boulders dominated the channel. The channel was well confined throughout the gorge, with few gravel bars. Those that did occur were tucked into breaks and crevices in the gorge walls or captured upstream of ledges and boulder dams.

Below the Green River Gorge, the river became a much more gentle, low-gradient river. Historically, the sediment carried by the river dropped out, and braided reaches formed in the middle Green River Valley. Prior to settlement, these reaches extended a considerable distance downstream, approximately to the Black River confluence in Renton. The middle and lower Green River originally carried a large load of sediment, because of the erosion of the relatively weak Cascadian rocks and surrounding glacial debris upstream. (Perkins 1993)

Lower Green/Duwamish Estuary

The lower Green/Duwamish Estuary was an area of very low gradient. Most of the larger sediment had been deposited in the middle river, and the lower river had primarily sand and mud substrate. Most of the lower reach of the river was affected by tidal influence, whether freshwater tidal or brackish tidal. It is known that the river had several distributary channels spread over the broad delta floodplain. LWD was carried into the lower river and estuary during floods. (Perkins 1993, Corps 1997a, 1997b)

3.2.2.2 Current Conditions

The prominent natural processes shaping the river include flooding and flow alterations, sediment transport, side-channel and geomorphic surface formation, riparian succession, and LWD recruitment. The Green/Duwamish River has undergone significant alterations to all major fluvial geomorphic processes, and these alterations have substantially changed the river's character and habitats. The middle and lower basin are discussed together in this section, and no analysis of the upper basin is included.

Flooding and Alterations in Flow

The construction of the Tacoma Diversion Dam, Howard Hanson Dam (HHD), and numerous levees along the river have reduced the migration of the river within the middle and lower basins, affected sediment transport, and reduced inundation of a significant portion of the historic floodplain. The HHD flood control operation eliminates flows sufficient to cause large-scale shifting or reconfiguring of the channel. Levees confine the river in numerous locations. Except for an area of braided multiple channels near O'Grady Park (RM 36.9 to RM 40.6), much of the river has assumed a single channel configuration. (Perkins 1993, Corps 1997a, 1997b)

Diminished channel length, less shoreline, and considerably less estuary characterize the channel in the middle and lower basin today compared to conditions at the time of European settlement. Measurements made from aerial photographs and maps supplied by the United States Geological Survey (USGS), the Corps, and other sources indicate significant decreases in channel length and width, as well as shoreline length. Decreases in channel length were mainly the result of levee projects that cut off multiple side channels and sloughs in the reach from Flaming Geyser Park (RM 43) downstream through Auburn (RM 33). In this reach, 18 percent of the channel is armored with levees. Between Auburn and Kent (RM 17), 80 percent of the channel has a levee or revetment on at least one bank. Overall, the river has been shortened by 10.4 miles from the estuary to the lower end of the Green River Gorge at RM 47 (Table 3-1). (Perkins 1993, Corps 1997a, 1997b)

Table 3-1. Selected Parameters of the Green/Duwamish Basin

Parameter	Pre-settlement	1936	1994	% Change (from pre-settlement to 1994)
Basin Area * Duwamish only ** Green only	1,640 sq. miles*	483 sq. miles**	483 sq. miles**	-70%
River/Stream Miles Accessible to Fish * three basins combined ** Green/Duwamish only	1,900 miles	580 miles* 83 miles**	380 miles* 125 miles**	-66% -93%
Estuary Area	3,950 acres[1]	298 acres	45 acres	-99%
Channel Length[2]	61 miles[3]	55 miles	50.6 miles	-17%
Shoreline Length	152 miles	121 miles	111 miles	-27%
Channel Width[4]	Unknown	277 feet	195 feet	-29% (between 1936 and 1994)

Notes:

1. Estimate includes tidal flats, tidal marsh, and tidal swamp.

2. Channel length is calculated for the Green/Duwamish River only. The estimate is from the estuary to the approximate downstream limit of the Green River Gorge at main RM 47.4.

3. Estimate includes some 21,000 feet of the Duwamish straightened during filling of the estuary and approximately 55,000 feet of braided channel and sloughs lost in the middle valley. It is a compilation of information from USGS maps and aerial photos and is an estimate of the maximum active river length for the period 1892 to 1936.

4. Estimate is a comparison of six cross sections within a reach in the middle Green River Valley between the Neeley Bridge at RM 35 and the Whitney Bridge at RM 39.

The river channel has also decreased in width as flood flows from the upper basin were controlled by the HHD and levees were constructed to contain the river. The average width of the middle Green River was 277 feet in 1936, and 195 feet in 1994, a reduction of 29 percent in channel width (Table 3-1). Much of the reduction in width appears to be related to the river being confined to one channel, where previously it had been quite migratory. Figure 3-2 compares the historic and current extent of the river's floodplain and migration. The channel in the lower Green River has also become narrower and formerly active gravel bars have stabilized due to encroachment of riparian vegetation (Perkins 2000).

Not only have channel length and width been altered, but shoreline miles have decreased proportionately. Calculations of shoreline per mile of undeveloped river channel in the Green/Duwamish River in 1936 suggest an approximate ratio of 2.2 to 1. By 1994, this ratio had decreased and there are now fewer irregularities in the shoreline, fewer bars and islands with sloughs, and less overflow from streams, all combining to reduce the lineal feet of shoreline. (Perkins 1993, Corps 1997a, 1997b)

In the lower Green/Duwamish River, the loss of shoreline is quite dramatic. The Duwamish Estuary is estimated to have had a shoreline of 93,000 feet and 3,950 acres of tidal mudflat, marsh, and swamp (Table 3-1). By 1986, there was a total of 45 acres of tidal mudflat and tidal marsh, and no tidal swamps. The estuary shoreline had been reduced to 72,000 feet with only 19,000 feet in riparian vegetation and the remaining 53,000 feet in developed shoreline. Approximately 21,000 feet of shoreline was lost in straightening the channel (Blomberg et al. 1988).

Historically, the combination of flood flows and the abrupt flattening of the channel at the end of the Green River Gorge (RM 47) caused the river to deposit its sediment load in the upper portion of the middle basin, creating braided channels in the mainstem of the river, a series of side channels, and numerous active geomorphic surfaces. This braided area once extended from the Green River Gorge to Auburn. Today braided channels are found only near O'Grady Park (RM 36.9 to RM 40.6). The present channel configuration in this reach was formed in 1959 by a flow approaching 30,000 cfs (Perkins 1993). Since 1959, except for a few small-scale channel shifts, the river has not created braided channels or side channels. Formation of braided channels, side channels, and active geomorphic surfaces has been substantially inhibited by the decrease in flood frequency and flow.

Alteration of the flow regime by HHD and the various diversions of the river's original flows have affected the river in another significant way. Historically, when flows inundated the adjacent floodplains, floodwaters seeped into the floodplain, recharging the water table. This water slowly drained toward the river over the year, supplying small floodplain streams, side channels, and the mainstem of the river with cool flows through the summer low flows. Without floodplain inundation, this process cannot occur, and floodplain streams and side channels dry up earlier in the season. River temperatures may also be affected by the loss of cool groundwater inputs during the summer low flows. (Perkins 1993, Corps 1997a, 1997b)

Reduced flows have also reduced water supply to the banks and geomorphic surfaces within the active channel. This has reduced overbank storage and affected riparian growth. Reduced soil moisture conditions have been found to lower the growth rate and survival of typical riparian plants. Ultimately this leads to a reduction in riparian width and the eventual replacement of typical riparian plant species with species tolerant of drier conditions. Surveys of riparian vegetation conducted in 1995 between O'Grady Park and Metzler Park, and examination of 1936 aerial photos, revealed that typical riparian species, such as Sitka spruce, cottonwood, and cedar, have been progressively replaced with mesic (moderately dry) species, such as Douglas-fir and Scot's broom, on the once flood-prone channel banks. (Perkins 1993, Corps 1997a, 1997b)

Howard Hanson Dam Additional Water Storage Project

Restoration of fish passage through HHD is the keystone of the Additional Water Storage Project ecosystem restoration. Improved fish passage, increased in-stream flows, and fish and wildlife habitat restoration measures all provide historic opportunities to restore and maintain self-sustaining and harvestable runs of salmon and steelhead for the Green River. The phased implementation and adaptive management measures proposed for the project allow for the flexibility to make adjustments to ensure the protection of fish and wildlife.

Key elements of the Additional Water Storage Project include:

1. New intake tower with new fish collection and transport facility including a wet-well, a floating fish collector, a fish lock, a discharge conduit, a fish transport pipeline, and monitoring equipment.

2. Mitigation features including management of riparian forests, planting of water-tolerant vegetation and maintenance of in-stream flows.

3. Ecosystem restoration features other than fish passage including gravel nourishment, a side channel reconnection project, and river and stream habitat improvements.

4. Right abutment drainage remediation.

5. New access bridge and access road.

6. New buildings, or additions to existing buildings, including an administration, maintenance and a generator building.

7. A change in reservoir operation (Phase I) to store 20,000 acre-feet of water to elevation 1,167 feet in the spring for release in the summer and fall (Corps 1998a).

Sediment Transport

The diversion of the White River and the development of HHD greatly reduced the sediment delivery to the lower and middle river. The diversion of the White River flows resulted in the loss of 75 percent of the original sediment loads to the Green/Duwamish River below its confluence with the White River (Dunne and Dietrich 1978). Perkins (1993), in her report on river migration, estimated that the HHD cut off sediment from 55 percent of the basin, an area that was the source of most of the sediment transported by the river. Some smaller-grained sediments are released through the dam, and through landslides and eroding banks, some sources of sediment are supplied to the river and floodplain below the dam. The loss of sediment from the upper river above HHD is contributing to the sediment reduction of the middle and lower Green River (Perkins 2000; Fuerstenberg et al. 1996). Reduction of natural river processes has diminished the frequency and extent of sedimentation. Historically, large floods between 15,000 and 30,000 cfs would topple trees along the river's edge, deposit sediment in the floodplain, and move river channels (Fuerstenberg et al. 1996). From completion of HHD in 1963, the maximum flow targeted at Auburn is 12,500 cfs, which precludes the kind of flooding and sediment deposition that occurred historically in the river valley. Today, the only mobile reach remaining in the middle and lower river is between Flaming Geyser State Park and Mueller Park (Fuerstenberg et al. 1996).

Side Channel Habitats

The formation of side channel and slough habitats, favored by several species of salmonids, is directly related to the processes of overbank flooding, channel migration, and sediment deposition. When the river moves from its original bed to a new location, either by gradual or catastrophic means, a new side channel may be formed. A preserved section of the old channel is known as a side channel. These channel shifts are common in sediment-rich systems where depositional areas create an unstable river bed. The Green/Duwamish River was historically a sediment-rich system that traveled widely over its floodplain and, as a consequence, had numerous abandoned river channels remaining as side channels to the main flow. (Perkins 1993, Corps 1997a, 1997b)

The reduction of river migration, sediment load and deposition, and overbank flooding has diminished the river's ability to form and maintain side channel habitats. A total of 51 side channels were identified in 1992 and 1994 photographs of the middle Green River (Fuerstenberg et al. 1996). Of these, 29 were field checked during the King County study (1996) for connection to the mainstem and quality of salmonid habitat. Many of the side channels are still connected to the mainstem and provide very good habitat. Several are disconnected and unusable by salmonids. The majority of the channels (28 total) are found in the Metzler/O'Grady Park area between RM 36.9 and RM 40.6, which is essentially the only remaining braided reach of the middle and lower basin. (Perkins 1993, Corps 1997a, 1997b)

Coccoli (1996) studied the effects of springtime flow alteration on side channel habitat in the Green River caused by HHD operations. She found that the frequency of connection for side and backbar channel habitat has declined over time as a result of water storage and diversion in the Green River, and that the current in-stream flow requirements from HHD were not adequate to achieve side channel habitat connectivity in some areas downstream of the dam.

The construction of levees and revetments has also limited the river's ability to carve or flood side channels. Just downstream from O'Grady Park, a large side channel complex was eliminated by the construction of a levee to protect the Green Valley Road (Fuerstenberg et al. 1996). At least eight side channels have been cut off from the river in this way.

There is very little side channel habitat on the lower Green River, except for a small area on the bank opposite Auburn (Fuerstenberg et al. 1996). Much of the habitat loss on the lower Green River was caused by the reduction in flow to the lower reaches and by the development of extensive levee systems. The levees have disconnected the river from its floodplain and reduced the river to a single, non-migratory channel.

Active Geomorphic Surfaces

Active geomorphic surfaces are areas that lie within the active floodplain and are characterized by a high probability of annual flooding, microtopography, and particle size. Most often, these areas are point bars, mid-channel islands, and other scoured surfaces within the migration zone of the active river channel. These surfaces are sites of rapid sediment, debris, and nutrient flux and are characteristic of depositional streams. They are areas of active sediment deposition, erosion, woody debris deposition, and rapid colonization by various plant species. Material stored or produced on these surfaces can be mobilized into the river's food chain during floods. Thus, they are often exceptionally important as ecological "hot spots." (Perkins 1993, Corps 1997a, 1997b)

Active geomorphic surfaces have decreased by 69 percent in the middle basin (Fuerstenberg et al. 1996). While some of these features have been lost due to the construction of levees and revetments, most appear to have been lost as a result of the decrease in the frequency of flooding and the consequent increase in scouring. Other active geomorphic surfaces have been stabilized with vegetation because floods are no longer large enough to disrupt the colonization of these areas by vegetation. Also, it appears that the river currently may be cutting deeper into its bed upstream of and through the remaining braided reach near O'Grady Park. In 1936, 236 acres of active geomorphic surfaces were present (Fuerstenberg et al. 1996). By 1992, the active surfaces had decreased to 78 acres, a decline of 69 percent. Approximately 80 percent of the remaining geomorphic surfaces lie in the O'Grady reach from RM 36.9 to RM 40.6, the remaining reach of the river that retains some pre-dam characteristics.

3.2.3 Hazardous Waste

Potential for hazardous wastes to enter the Green/Duwamish River and consequent sediment contamination is of most concern in the lower river. Urban and industrial development within the lower Green/Duwamish River has resulted in numerous contaminant sources, including industrial discharges, combined sewer overflows, stormwater runoff and shipping-related sources (accidental spills, treated pilings) (Tetra Tech 1998). Sediment sampling in the lower Green/ Duwamish River has identified several contaminants of concern in sediments, including oil and grease, sulfides, pesticides, polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons (PAHs) (Corps 1995; Corps 2000).

3.3 Water Resources

3.3.1 Surface Water

3.3.1.1 Water Supply

The upper basin is the primary area of water supply for the City of Tacoma as a result of the Tacoma Diversion Dam constructed in 1911 at RM 61. The Tacoma Water Department currently is allowed to remove up to 113 cfs for water supply (Corps 1998b). Washington Department of Ecology (Ecology) maintains a database of water rights granted in each basin. The Green/Duwamish Basin surface water rights database shows that 3,253,578 cubic meters of water are granted each year to all the legal water rights holders with specified withdrawals (not including the City of Tacoma). The holders with specified withdrawals make up approximately 20 percent of all water rights granted in the basin. This volume of surface water is 2 percent of the amount diverted by the City of Tacoma. Extrapolating to all legal surface water rights holders, approximately 16,300,000 cubic meters of water are diverted annually from the Green/Duwamish Basin in addition to the City of Tacoma's diversion. Groundwater withdrawals are presumed to be of comparable magnitude. Most of the withdrawals are for irrigation and domestic water supply. (Corps 1997b)

3.3.1.2 Hydrology

Historic Conditions

Upper Basin. In the upper basin, the river falls from its headwaters near Stampede Pass over steep, mountainous terrain restricted by narrow valley walls. The upper basin has a drainage of 221 square miles in the Cascade Range.

In its historic condition, the upper basin was forested and had complete canopy closure except for natural burns, landslides, and avalanches. In this condition, several factors regulated the hydrology of the mainstem and its tributaries. Rain and snow were first intercepted by the canopy. Raindrops would be broken into smaller fragments, increasing evaporation rates. Snow suspended in the canopy would be partially lost to wind and evaporation. The duff layer on the forest floor absorbed quantities of water and slowed its movement into small streams. Beneath the canopy, air temperatures were cooler in the spring and snow remained longer. The cumulative effects of the forested historic condition were to slow the rate of runoff during storm events and extend the period of higher flows in the spring. (Corps 1997a)

Snow was one of the predominant influences on hydrology in the upper basin, with over 50 percent of the basin experiencing it as the major form of precipitation. Over one-third of the basin lies in the rain-on-snow zone. Historically, there was great variability in peak flows, and downstream flooding regularly occurred in the spring and late fall. There was also a wide amount of variability in precipitation in the upper basin due to variability in elevation and aspect. Some local areas of more intense storm precipitation do exist, such as Smay, Sweeney, and Tacoma Creeks (USFS 1996).

Historic flow patterns in the upper basin were the typical bi-modal distribution found in much of the western Cascade Mountains. Usually, high flows occurred in winter (November through January) and spring (April through May), with May having the highest mean monthly flow and November and December the highest peak flows. This shows the typical pattern of a basin with a significant portion in the rain-on-snow zone. (Corps 1997a)

Middle Basin. Historically, the middle Green River collected flows from the White, Black, and Cedar Rivers. The White River occasionally spilled over into the Puyallup River during high flows, but never long enough or in sufficient quantity to establish a permanent channel into the Puyallup River. The permanent diversion of the White River into the Puyallup River Basin through the Stuck River in 1898 decreased flood damages in the middle Green River Basin and reduced the historic flows in the middle and lower Green River by approximately 50 percent. (Corps 1997a)

A system of levees was constructed along the lower portion of the middle basin from near Auburn, continuing downstream to the Duwamish River near Tukwila. The levee system was built by many different land owners and government agencies. Farmers were the first to construct levees to keep flood waters out of their fields and extend the growing season. Prior to levee construction and industrialization, the river would overflow its banks during high flows and spread out into relatively flat, adjacent wetland areas. The river meandered and the channel location shifted over time. The high flows were attenuated by overbank storage provided by the extensive adjacent wetland areas.

Prior to construction of the HHD in 1963, large floods sent up to 7 feet of water flowing across the landscape of present-day Auburn. The maximum, mean daily regulated discharge near Auburn was approximately 12,800 cfs; the highest recorded flow was 28,100 cfs in 1937. The river meandered and the channel location shifted over time. The high flows were attenuated by overbank storage provided by the extensive adjacent wetland areas. (Corps 1997a)

Lower Green/Duwamish Estuary. Prior to 1900, the Duwamish Estuary was fed by the basin areas of the Cedar, Black, Green, and White Rivers (including drainage areas of Lake Sammamish and Lake Washington). The undeveloped Duwamish drainage area of approximately 1,640 square miles contributed an estimated 2,500 to 9,000 cfs of fresh water to the estuary environment. (Corps 1997a)

Early records indicate that the estuary was characterized by a river meandering through significant areas of tidal marshes and swamp lands. The fresh water entered Puget Sound via three main distributor channels. A major portion of the south end of Elliott Bay included broad, intertidal flats and shallows. The estimated area of the Duwamish Estuary prior to development was about 4.3 square miles. (Corps 1997a)

Tributaries. Originally, much of the land in and around the tributaries supported wetland plants, fish, and animals. Human settlement, however, dramatically changed the hydrologic framework of the Green River Basin. During the early settlement period in the region, the seasonally flooded bottom-lands were cleared and filled. Lands that had been drained, logged, and put into crop production during the early part of the area's history were often filled and used as building sites during the more recent periods of commercial and industrial growth.

Current Conditions

The Green/Duwamish River is fed by runoff from rainfall and groundwater inflows, along with snowmelt from the upper elevations. The tributaries throughout the basin collect surface waters and direct them into the mainstem of the Green River. The flow regime of the Green/Duwamish River generally follows that of other west slope Cascade Range rivers, with a characteristic seasonal double peak indicating the effect of winter rainfall and a spring peak from combined rainfall and snowmelt. (Corps 1997a)

Large flood events are generally the result of warm rainfall melting an already existing significant snowpack from October to March. The runoff is primarily the result of direct rainfall but may be augmented by rain-on-snow events during the early winter. Highest flows generally occur in December or January, declining through March with a subsequent snowmelt peak in April or May. (Corps 1997a)

With the construction of HHD in 1963, sufficient storage was provided to control the Green/Duwamish River flows to bankfull (approximately 12,500 cfs) at the U.S. Geological Survey (USGS) flow gage at Auburn. The Corps operates the dam for flood control, catching runoff peaks and storing flood water in the reservoir before it floods the lower Green/Duwamish Basin. The dam provides flood protection up to the 500-year event. As a consequence, since 1963 there have been almost no discharges above the regulated high flow of 12,500 cfs at Auburn. Today there is very little difference between the 2-, 5-, 10-, 25-, and 50-year events downstream of the dam; all range between 11,000 to 12,500 cfs. Flood events that inundated the adjacent floodplain no longer occur, and large, channel-altering flows have an extremely low probability of occurrence. (Corps 1997a)

Post-dam records from 1963 to 1994 record a mean peak discharge of 8,800 cfs, a decrease of some 31 percent from the pre-dam mean peak discharge of 12,800 cfs. Post-dam maximums are controlled to the regulated release of 12,500 cfs at Auburn; the pre-dam recorded maximum was 28,100 cfs. Because the dam limits the volume of water allowed to flow during a flood, the dam also lengthens the time the channel is subjected to the controlled flow. Thus, the duration of the regulated flow from the dam is often longer than the duration of that same flow in the pre-dam condition. (Corps 1997a)

However, the dam does not control all flooding along the river. Localized flooding still occurs because many tributary streams cannot drain into the leveed banks of the Green River during flood stage. In some areas, tributary water is pumped into the Green River during these events.

In general, low flows in the river are affected by reduced upper basin runoff after snowmelt and by the Tacoma Diversion Dam. The Tacoma Diversion Dam currently removes up to 113 cfs. Minimum stream flows in the river occur between July and November and are most frequent in August and September. The lowest flow recorded at Auburn was 81 cfs and occurred in September 1952. Prior to construction of HHD, flows above the Tacoma Diversion Dam fell below 150 cfs every other year on average and below 100 cfs every 9 years on average. Operations of HHD and the reservoir are regulated to provide both flood control and to augment low summer flows in the mainstem for fisheries conservation. This regulated flow regime has reduced the frequency of low flows less than 150 cfs to approximately one in every six years, on average, and flows less than 100 cfs to less than once in 50 years. (Corps 1997a)

Upper Basin. Much of the upper basin is within the protected City of Tacoma watershed. Except for HHD, there is little stream-side development in the upper basin except for logging roads, bridges, a railway, and numerous culverts. Operation of HHD and the reservoir has three major components including winter flood operations, spring refill, and summer flow augmentation.

The winter flood season from October through March is characterized by drafting the reservoir and lowering pool levels to allow for flood storage. Flows are regulated manually at the dam with direction from the Corps Water Management Section. The reservoir is drawn down in normal years to an elevation around 1,070 feet by November 1 to provide full flood storage capacity in the reservoir. The reservoir is kept as low as possible during the flood season so that runoff from the basin above HHD can be impounded when needed. Normal river flows pass through the outlet tunnel in the dam's left abutment. When the river flow reaches flood stage, discharge from the dam is reduced and water is impounded in the reservoir. As river flows return to normal following a flood, the water impounded in the reservoir is released at a rate that ensures safe discharge within channel capacity in the downstream area and minimizes damage to levees from sloughing during evacuation of storage. During the winter months, flow from the reservoir is regulated to a maximum of 12,500 cfs at Auburn during flood events (Figure 3-3). The highest pool elevation attained in the reservoir during flood storage was 1,183 feet in 1996. To date, it has not been necessary to use the spillway. Spring refill operations occur from mid-March through early June. During this operation period, the pool is raised from the winter low level of about 1,070 feet to about 1,141 feet of storage water to augment summer flows for fisheries conservation. During the summer flow augmentation period, the reservoir is slowly drafted to increase downstream flows. (Corps 1997a)

During the flood season, the unregulated and regulated flows are closely matched. During the spring refill season the regulated flows are typically lower than the unregulated flows while extra water is being stored for summer flow augmentation. During the summer flow augmentation period, the regulated flows are typically higher than the unregulated flows, indicating successful augmentation operation.

The timing of the spring refill period depends on spring rainfall and an estimate of the upper basin snowpack water content as measured in March and April. During the high runoff year of 1974, the spring refill began around the middle of June. During the low runoff year of 1978, the spring refill began much earlier at the beginning of May. The spring refill began much later during 1974 due to abundant precipitation and a large snowpack in the mountains. The abundant snowpack allowed for a much later refill of the reservoir due to anticipated higher inflows to Howard Hanson Reservoir. The small snowpack in 1978 mandated that the refill begin earlier, in order to ensure that the reservoir would refill. (Corps 1997a)

HHD has a range of operational choices within the parameters of these authorized uses of the dam. Throughout the years that HHD has been in operation, many downstream changes have occurred in land use, recreation, fisheries, resource allocation, and environmental awareness. All these external influences have resulted in operational changes and adjustments, primarily manifested in the refill timing of the conservation pool and the in-stream flow needs. This history of operational modification is discussed in more detail in the Final Environmental Impact Statement for Operation and Maintenance for Howard Hanson Dam (Corps 1996b).

Additional modifications to the operation of the HHD could further influence the hydrologic conditions of the upper basin. The intent of any operational changes is to provide the most responsive and equitable utilization of water among sometimes competing resource users. Ongoing projects that could influence that hydrologic conditions of the upper basin/reservoir are:

- The Howard Hanson Additional Storage and Ecosystem Restoration Study evaluated the feasibility of increasing reservoir storage for municipal water supply and additional low-flow augmentation, as well as adding downstream fish passage facilities and habitat improvement measures.

- The Howard Hanson Section 1135 evaluated the feasibility of increasing storage behind the reservoir strictly for low-flow augmentation. (Corps 1997a)

Middle Basin. In general, operation of the HHD and Howard Hanson Reservoir regulation have increased flows below the dam during the winter flood season drawdown, decreased flows during spring refill, and increased flows during the summer flow augmentation. These differences in the regulated and unregulated flows result from the effects of regulation during the winter flood operation, spring refill, and summer flow augmentation. (Corps 1997a)

Discontinuous levees are present along much of the middle Green River. These are short sections of levees built on one side of the channel to protect private residences and property. The levees have channeled and straightened the middle and lower Green River, and also increased the velocity of flows through the middle basin due to reduced overbank storage, and the channeling effects of levees. Overbank storage was historically provided by the wetlands and floodplains associated with the river and helped alternate flows, minimizing peak flows and maximizing low flows. Confining the river to a single channel has essentially cut the river off from its historic overbank storage, resulting in a loss of flow attenuation. Increased urbanization in the middle basin has also affected flow velocity and attenuation. (Corps 1997a)

The middle Green River Basin has become increasingly urbanized as the area's economy and population have grown. In general, urbanization creates areas of impermeable land in the basin. The creation of impermeable surfaces reduces the rate and quantity of infiltration and increases the rate and quantity of surface runoff during storms. In general, the river reaches a peak flow more quickly, and the peak is higher in a basin which has undergone urbanization and industrialization. (Corps 1997a)

Lower Green/Duwamish Estuary. The conditions in the lower Green/Duwamish Estuary today are greatly changed compared to conditions before 1900. The diversion of the White and Cedar Rivers, and the blockage of the Black River, have decreased the freshwater drainage area of the Duwamish Estuary from 1,640 square miles to 500 square miles, a decrease of 70 percent. The annual freshwater discharge to the estuary is also approximately 70 percent less than discharges prior to 1900. Currently, the only significant freshwater source to the estuary is the Green/Duwamish River Basin discharge. (Corps 1997a)

Historically, freshwater entered the Duwamish Estuary through several, dynamic channels of the lower Green/Duwamish River. Over the last 100 years, the braided flows of the lower river have been extensively channelized through dredging and construction of levees. Presently, freshwater enters the estuary through one permanent channel. A general increase in the distance of saltwater intrusions inland has been documented and is largely attributed to the loss of freshwater flows. The decrease in freshwater flows has also led to an increase in the rate of bottom sediment buildup in the estuary. (Corps 1997a)

Tributaries. The upper tributaries including Sunday Creek, Smay Creek, and the North Fork lie in the snow zone and exhibit seasonal, bi-modal discharge peaks indicative of increased flows due to fall rain and spring snowmelt. The lower basin tributaries including Newaukum Creek, Soos Creek, and Mill Creek do not lie in the snow zone and typically have a single runoff peak in December or January.

Newaukum Creek. Newaukum Creek joins the Green River near Black Diamond. Summer flows in Newaukum Creek have been declining over the past four decades because of groundwater withdrawals (Fuerstenberg et al. 1996).

Soos Creek. The Soos Creek system consists of Big Soos Creek and approximately 25 tributaries. The system has over 60 miles of streams and drains an area of nearly 70 square miles. The upper sections of Big Soos Creek are characterized by heavily wooded riparian corridors interspersed with pastures and increasing residential development.

The Soos Creek system is hydrologically complex with many lakes, wetlands, and a high level of interaction between surface water and groundwater. Existing development in the basin ranges from rural to high-density urban. A number of flow-related problems have been associated with the increasing urban development. As the amount of impervious surface in the Soos Creek sub-basin continues to increase, peak flood flows have also increased and flow alternatives have diminished. Along with high winter flood flows, low summer flows have also been observed. With increasing impervious surfaces, less water is captured and stored in the sub-basin's wetlands and aquifers, reducing water supplies for the summer flows. (Corps 1997a)

Mill Creek/Mullen Slough. The Mill Creek and Mullen Slough drainages cover a combined area of about 22 square miles on the west side of the Green River. This sub-basin extends into portions of the cities of Kent, Auburn, Federal Way, and Algona, in addition to unincorporated parts of King County. The sub-basin covers three types of drainage areas: the very flat Green River Valley floor, the steep slopes along the western edge of the valley, and the rolling upland plateau on which the principal headwater tributaries are formed. (Corps 1997a)

Runoff from the upland plateau flows down to the Green River Valley floor in a series of steep well-incised ravines. At the valley floor, water courses flatten and flow north through the Green River Valley via Mill Creek to the Green River. The valley floor itself is drained by a complex network of low-gradient ditches and agricultural drains that contribute further flows to the mainstreams of Mill Creek. Flows from the valley floor to Mill Creek have increased dramatically in recent years as a result of increased development. (Corps 1997a)

Under current conditions, flooding in the lowest reaches of Mill Creek and Mullen Slough is controlled by the backwater effects of the Green River. High flows on the Green River can result in the inundation of up to about 900 acres of agricultural land in the Mill Creek/Mullen Slough sub-basin. (Corps 1997a)

3.3.1.3 Flooding and Flood Control

Upper Basin

HHD is located at RM 64.5. Since completion of construction in 1963 the primary authorized uses of the dam have been flood control and augmentation of summer low flows in the Green River. Two secondary future uses are also authorized but not implemented: irrigation and water supply. The Corps operates the dam for flood control, catching runoff peaks and storing flood waters in the reservoir before they flood the lower Green/Duwamish Basin. Operation of the HHD and reservoir controls the discharge at the Auburn gage to 12,500 cfs for the standard project flood (approximately a 500-year event) and provides a minimum of 110 cfs in-stream flow during all summer months. The reservoir (conservation pool) extends about 4 miles eastward from the dam along the main river channel and 2 miles northerly up the North Fork of the Green River. The pool is normally maintained at a minimum level (about elevation 1,070 feet) from October to March to provide flood storage space. At full conservation pool level, the reservoir impounds 25,400 acre-feet, with a surface area of 732 acres. Flows are regulated manually at the dam with direction from the Corps Water Management Section. The project controls the drainage of 221 square miles of basin in the Cascade Range, about 50 percent of the basin. (Corps 1997b)

Middle Basin

The southern portion of the middle Green River Basin has been developed primarily for agricultural use, and much of the original forests and riparian zones have been cleared for pasture. The floodplain of the river in this area has been constrained locally with levees to protect bridges, roads, and homes. The safe channel capacity through this reach of the river is about 12,500 cfs. At this discharge the channel banks are nearly full, and some backwater occurs in minor tributaries. Discharges of this magnitude have periodically occurred over the past 30 years without levee overtopping or breaching, although local areas of bank failure have occurred. The stability of the levees becomes more questionable as the duration of high flows increases. (Corps 1997b)

Under the authority of Section 205 of the 1948 Flood Control Act, two projects were constructed on the Green River: one in the City of Tukwila and one at Horseshoe Bend in Kent. These projects provide protection from the standard project flood (SPF) and protect commercial and industrial areas in both cities. The project consists of modifications and improvements to an existing levee system. Also included are erosion control (gabion walls and vegetative ground covers), provision for interior drainage, and landscape restoration. King County and the local levee district have also constructed numerous levees throughout the lower half of the basin. (Corps 1997b)

Lower Basin

The lower Green/Duwamish Basin begins at Ft. Dent Park near the City of Tukwila at approximately RM 11. Here the Green River is commonly referred to as the Duwamish River as it flows northward into the Duwamish Estuary at Elliott Bay. The river is leveed on both sides and increasingly channelized as it passes through Tukwila. By the time the river passes through the industrialized areas of south Seattle, it is completely contained in the Duwamish River. (Corps 1997b)

3.3.2 Groundwater

The Green/Duwamish Basin downstream from the Green River Gorge lies within the Southwest King County Groundwater Management Area. The USGS published a groundwater report for this area in 1995 that gives a more complete description of groundwater for the area (Woodward et al. 1995).

Subsurface glacial deposits and Holocene alluvium define the water-bearing geology of much of the basin. Glacial deposits in the basin are up to 2,200 feet thick, the result of four periods of continental glaciation. Woodward et al. (1995) describe the dependence of the local groundwater on geology as follows: “The groundwater-water flow system is affected by the complexity and heterogeneity of the sediments that underlie the study area. A glacial aquifer may be composed of predominantly sand- and gravel-sized sediments, but at a small scale, it probably also contains relatively thin and discontinuous lenses of silt and clay or intermixed coarse and fine-grained sediments. The occurrence and movement of groundwater locally is influenced by these small-scale variations in lithology and by their extent.” A generalized diagram of the groundwater movement in southwestern King County including part of the middle and lower Green/ Duwamish Basin is shown in Figure 3-4.

Samples from existing wells indicate that groundwater quality is generally good with no widespread degradation of groundwater quality in southwestern King County (Woodward et al. 1995).

Natural recharge to the aquifer system is from precipitation infiltration, and infiltration from streams, lakes, and wetlands (Woodward et al. 1995). Modeled recharge is low in the lower basin (Woodward et al. 1995); this area has a large percentage of impervious surfaces and consequently more precipitation runs off as surface flow.

Groundwater conditions in the upper basin have not been investigated.

3.4 Water Quality

3.4.1 Historic Conditions

3.4.1.1 Upper Basin

Historically, the upper portion of the Green/Duwamish River Basin was similar to higher basins throughout western Washington. These basins were typically edged by a mixture of tall trees and bushy shrubs. This thick vegetation shaded streams to maintain cool water. Although flooding and soil movement did occur in major storm events, runoff within the upper basin was generally slower moving, overland sheet flow rather than faster, channelized flow. Sediment and large woody debris (LWD) inputs to the upper basin were significant (Perkins 2000).

Prior to the construction of the Tacoma Diversion Dam at RM 61, anadromous fish were able to enter the upper basin, spawn, and die. Their carcasses returned nutrients and contributed to a biologically productive stream. Seasonal stream temperature trends downstream of RM 64 were quite different prior to construction of HHD in 1963. From June to mid-July, natural water temperatures were warmer than they are today. From August until the fall rains begin, water temperatures were colder. From November through May, stream temperatures would have been about the same as they are today. Prior to construction of HHD at RM 64, stream temperatures between RM 64 and RM 47 were likely colder than they are today. (Corps 1997a)

3.4.1.2 Middle Basin

The middle portion of the Green/Duwamish River included an upper steep stretch, and a lower flat stretch. The steeper area had dense growth of large streamside trees that provided debris in the river and shade to maintain cooler water. The flatter stretch was a wide system of braided channels with intermittently connected sloughs and wetlands. Dense vegetation along the sides of the river and its tributaries provided shade.

The natural system of wetlands associated with the middle Green/Duwamish River buffered the river from storms and droughts. High streamflows in the winter and spring were attenuated by the stormwater detention function of wetlands. Wetlands allowed more water to seep into the shallow groundwater aquifers and naturally supplemented summer and fall low flows. Groundwater is generally naturally cooler than surface water, resulting in streams with better water quality. Historically, summer low flows were an additional 113 cfs higher due to the portion of water now diverted by the Tacoma Diversion Dam. (Corps 1997a)

3.4.1.3 Lower Basin

The lower portion of the Green/Duwamish River was once a system of braided channels from approximately RM 6 to Elliott Bay. The summer flows prior to the diversions of the White and Cedar Rivers and the construction of the Tacoma Diversion Dam and HHD were larger than current summer flows. The White River, which drains a portion of glaciated Mt. Rainier, contributed glacial snowmelt (glacial flour). Large woody debris, streamside shading, and riparian wetlands associated with the predeveloped lower Green/Duwamish River all likely provided stream structure and higher water quality. (Corps 1997a)

3.4.2 Current Conditions

The Washington State Department of Ecology is responsible for setting water quality standards based on water use and water quality criteria. The five water quality classes are:

- AA: extraordinary
- A: excellent
- B: good
- C: fair
- Lake

The majority of the Green River and its tributaries are designated as Class A waters. Class A waters can be used for water supply, stock watering, fish and wildlife habitat, and recreation. While the Green River maintains its high water quality rating, it also appears on Ecology's list of impaired waters. The mainstem of the river and many of its tributaries regularly exceed parameters for Class A waters. (Corps 1997a)

The Duwamish River segment of the drainage (RM 11 to 0) contains intense industrial development and is the only section of the river system designated as Class B waters. At the other extreme, the portion of the river between Flaming Geyser State Park (RM 42) and the river's source in the upper basin is classified as Class AA waters by Ecology (Corps 1996b). The intervening segments of the river have a range of water quality between these two extremes as the river flows through its increasingly urbanized basin. (Corps 1997a)

3.4.2.1 Upper Basin

Temperature

Extensive logging of the upper basin has affected stream temperatures because of a smaller vegetative buffer and less shading along the stream. Several streams are on the 303(d) list for temperature. However, most streams have stream temperatures that are below Washington State surface water quality standards with a few brief exceedances above the standard. (Corps 1997a)

Nutrients and Dissolved Oxygen

There are areas of localized elevation of stream temperatures and lower dissolved oxygen (DO) due to streamside logging and subsequent solar radiation. With these exceptions, DO is close to 100 percent saturation in the entire water column. Howard Hanson Reservoir is oligotrophic with no significant algae blooms or lacustrine macrophyte growth. (Corps 1997a)

The recycling of nutrients and sediments depends on the ability of the river to flood and, as it does so, move and carry sediment. HHD reduces flow volume, rate, and sediment passage; the levees and revetments reduce river migration rates. Reduction of these natural river processes reduces the frequency and extent of sedimentation and slows the natural progression of plant succession that would normally occur in the riparian zone. Historically, large floods would knock out trees along the river's edge, deposit sediment in the floodplain, and move river channels. Since dam completion in 1963, the maximum flow allowed at Auburn is 12,500 cfs, which precludes the kind of flooding that occurred historically in the river valley. Data from 1937 through 1993 show three annual peaks over 20,000 cfs occurring between 1951 and 1960. Some sediment is still released by the dam, and landslides (e.g., Hammond Bluff) and eroding banks supply some sediment to the river and floodplain below HHD. (Corps 1997a)

A reduction in vegetation in the riparian zone reduces the recycling of nutrients between the terrestrial and the aquatic system. Vegetation growing at the river's edge produces leaf litter, which provides food for aquatic insects (e.g., leaf scrapers) and other species of the riverine food web. Bilby et al. (1996) found that riparian foliage is an important source of carbon and nitrogen input to stream systems, and that carbon and nitrogen transported in stream systems by returning salmon is linked with the tissues of aquatic organisms and riparian plants.

Fecal Coliform

Development and recreation activities are restricted in the upper basin, resulting in no significant human fecal coliform sources. Animal fecal coliform sources in the upper basin occur from wildlife populations in the immediate vicinity of the mainstem and tributaries. (Corps 1997a)

Turbidity and Suspended Sediment

Turbidity and suspended sediment levels are generally very low, with the exception of occasional high winter and spring levels. Extensive logging in the upper basin has increased turbidity and suspended sediment levels as a result of removal of the vegetative buffer along the streams and disturbances to surface soils. The construction of logging roads has increased the sediment load of large winter and spring runoff events. (Corps 1997a)

The U.S. Forest Service (USFS) has estimated that 824 miles of roads exist in the upper basin (USFS 1996). Approximately 34.5 miles of road have been decommissioned. Roads, especially older roads, can contribute significant quantities of fine sediments to the streams and the upper Green River. Plum Creek Timber Company estimated that the main road along the upper river contributes over 150 tons per year of sediment to the upper Green River (Plum Creek 1996). Additionally, roads on steep slopes can cause mass wasting events, which may cause large debris flows into streambeds. Suspended sediment in upper basin streams eventually enters the Howard Hanson Reservoir. While studies have shown no net accretion of sediment in the reservoir, it is likely that larger, heavier particles are depositing in the river just upstream of the reservoir, while smaller particles are carried downstream of the dam.

Metals and Toxics

Analytical results of water quality sampling in Howard A. Hanson Reservoir indicate the water has very good chemical quality. Analyses performed annually by the City of Tacoma indicate that raw water quality conforms to State inorganic chemical criteria (Corps 1998b).

3.4.2.2 Middle Basin

Temperature

Howard Hanson Reservoir has a dramatic effect on river temperatures downstream from the dam from June through October. As reservoir filling for low flow augmentation begins in early spring, water on the surface of the reservoir begins to warm. HHD's outlet draws water from the bottom of the reservoir that is colder than the water entering the reservoir. As a result, water exiting the dam in June and early July can be 2^{o} to 4^{o}F colder than water entering the reservoir. As summer progresses, stored cold water is depleted and the dam releases water that has been absorbing heat from the sun over the summer. Outflow temperatures are generally higher than inflow temperatures from August until the fall rains begin. The combination of channel width, depth, and lack of shade-producing riparian vegetation also contributes to warming of the river during low flow periods in summer. (Corps 1997a)

The height and density of the canopy is a factor in the production of shade (Brazier and Brown 1973). In 1994, the average width of the lower Green/ Duwamish River was about 110 feet, and the average width of the middle Green/Duwamish River was about 194 feet (Blomquist pers. comm.). At high noon on a summer day, most of the river's water would be exposed to direct sunlight. At 9 a.m. and 3 p.m., trees would have to be as tall as the river is wide to provide complete shading of the water, depending on the orientation of the river flow (north or west) and the density of the canopy. Trees would have to grow for hundreds of years to reach the 100 to 200 feet necessary to provide shading of the river. Maximum tree height on the Green/Duwamish River today is estimated to range from 60 to 80 feet where the trees occur (36 percent of the river's edge), while shrub vegetation (33 percent) is a maximum of 20 feet high. About 30 percent of the river's edge is grass or pavement providing no shade to the river. Brazier and Brown (1973) report that "the thicker canopies of conifers are more efficient traps of radiation than the thin canopies of hardwoods even though the densities may be the same." Conifers constitute only 1 percent of the vegetation along the river's edge, and therefore contribute little to thermal protection of the river.

Hewlett and Fortson (1982) suggest that the temperature of effluent groundwater was a possible cause of elevated temperatures in streams (due to the effect of elevated soil temperatures outside the buffer). However, the probability of decreasing the sun's effect on river water temperatures through shading of soil outside of the riparian zone is very small.

Nutrients and Dissolved Oxygen

Generally, nitrate and ammonia levels in the middle Green River are highest during the winter. This reflects their source from stormwater runoff, stormwater outfalls, and failing septic systems (METRO 1978). In addition, during periods of summer low flows, significant levels of ammonia from livestock and other non-point sources are quickly converted to nitrate, with a resulting depletion in DO.

Fecal Coliform

Fecal coliform pollutants are contributed to the tributaries and the mainstem Green River from domestic animals pastured along the river.

Turbidity and Suspended Sediment

Stormwater runoff is much faster across agricultural lands than forested lands. When agricultural lands are fallow and unvegetated during the rainy season, significant amounts of fine sediment can be transported to the river. Turbidity in this section of the river is not thought to be limiting to fish (Corps 1995b). With the exception of increased turbidity levels during high flow events, high turbidity is not currently a problem. There may be, however, a shortage of fish spawning gravels in the middle basin. Gravels from the upper basin, possibly entrained during storm flows, are dropped in the reservoir. Finer sediments are carried through the reservoir, thus settling in the channel of the middle and lower basin.

Metals and Toxics

Agricultural lands contribute pollutants in the form of fertilizers and pesticides. The current trend in the middle basin is toward residential development of former agricultural lands. This has dramatically increased the amount of impervious surfaces and stormwater runoff in the middle basin, as well as increasing pollutants, such as petroleum products and fertilizers. (Corps 1997a)

Continued development of the middle basin is expected to contribute lead, zinc, petroleum, and copper to the river from non-point sources. Mercury may also leach from minerals and mines in the upper and middle basins (METRO 1982). Metals can be toxic to both humans and aquatic organisms and can persist in the environment.

3.4.2.3 Lower Basin

The lower basin is divided into the freshwater portion (above RM 6) and the estuarine portion (from RM 6 to Elliott Bay). During the summer low flows, tidal influence extends upriver to RM 12. Water quality in the estuarine section is detailed in Seaboard Lumber Site, Aquatic Restoration Analyses (Corps 1995b). Analysis of the predominantly freshwater portion of the lower basin is described below.

Temperature

King County and Ecology have both recorded numerous instances of water temperature in the lower Green/Duwamish River exceeding the Washington State criteria for Class A waters. Specifically, water temperatures greater than 64^{o}F were measured 58 times between January 1, 1988 and July 1, 1996 (Ecology 1994).

Surface water temperature in the Duwamish River is dependent upon the temperature in the Green River system. Surface flow temperatures ranged from 45.6°F in late March to 67.1°F in early August at nine sampling sites located from Duwamish RM 1.6 to 10.4 (Warner and Fritz 1995). In the Turning Basin water temperatures have varied from 36.5 to 64.0°F (Muckleshoot

Indian Tribe Fisheries Department, unpub. data). In the lower Duwamish, water temperature is primarily influenced by the relative temperatures of the freshwater inflow and the salt water intruded from Elliott Bay (Warner and Fritz 1995). This salt-water intrusion profoundly influences water temperature at various depths in the Turning Basin (Muckleshoot Indian Tribe Fisheries Department, unpub. data). In January, water temperatures measured at 1-meter depths can increase from 36.5 to 46.8°F over a depth of 8 meters (26.2 feet). In May, temperature measured at 1-meter (3.3 feet) depths can decrease from 63.9 to 52.9°F measured over a total depth of 4 meters (13.1 feet). In September, temperatures are more uniform decreasing from 61.9 to 56.8°F. The range of temperatures over depth is also influenced by the tidal stage. The variation in water temperature with depth provides adult and juvenile salmonids some refuge from the higher temperatures. However, in the late summer and early fall, the general range of temperatures offers no refuge from temperatures considered outside the preferred range.

Lack of large vegetation in the riparian zone has also been cited as a significant cause of elevated temperatures. The role of vegetation as an effective buffer against increasing water temperatures caused by direct sun exposure is probably minimal for the Green/Duwamish River. However, it was probably not always so. The literature addresses the role of vegetation in retarding the increase of water temperatures in streams and rivers (Marlega 1970, Brazier and Brown 1973, Hewlett and Fortson 1982). “The magnitude of temperature change is dependent on the discharge or streamflow, surface area exposed to sunlight and the amount of radiation received from the sun” (Brazier and Brown 1973).

Nutrients and Dissolved Oxygen

Nutrient loads carried by the lower Green/Duwamish River may contribute to freshwater algal blooms in the Duwamish River. Generally, nitrate and ammonia levels are greatest during the winter months, because of stormwater runoff, combined sewer overflows, and failing septic systems (METRO 1978).

Higher nutrient levels in the summer contribute to low DO through nitrification of ammonia and decay of algae blooms. Oxidation demand of industrial runoff further contributes to low DO. Measurements of DO in the lower Green/Duwamish River have revealed 52 instances between July 1987 and July 1994 when DO levels were below the criteria for Class A waters (Ecology 1995).

Fecal Coliform

The state water quality standard established for fecal coliform was exceeded 204 times from July 1987 to January 1992 in the lower Green/Duwamish River (Ecology 1995). Storm events play a role in increased fecal coliform levels. Stormwater runoff carries animal waste into the river and its tributaries from agricultural land. In addition, the functional life span of the septic systems for some of the early developments along the river has been exceeded. As a result, failing septic systems may be contributing to the elevated coliform levels measured between the cities of Auburn and Kent (King County 1994).

Turbidity and Suspended Sediment

With the exception of increased turbidity levels during high flow events, high turbidity is not currently a problem in the lower river. Springbrook Creek, in particular, contributes higher turbidity levels to this section of the river.

The cumulative impact of urbanization on sediment loads in basins can be dramatic. Erosion from developing urban areas can produce suspended sediment loads 10 times greater than undisturbed areas (King County 1994). The sudden increase in flows caused by stormwater events can erode stream banks and further increase siltation. Loss of wetlands, useful for filtering runoff and moderating flows, further increases the flows and fine sediment loads of small stormwater events.

Metals and Toxics

Mercury and chromium levels above state established standards have been recorded (Ecology 1995). Mercury levels were high in the lower river until 1987 when the Renton Treatment Plant rerouted its wastewater discharges out of the Black River/Springbrook drainages. An additional source of metals in the river may be leachate from the now closed Kent Highlands Landfill (METRO 1978).

Agricultural and industrial practices have released organic and inorganic pollutants into the lower river. Water quality sampling conducted by the U.S. Environmental Protection Agency (EPA) has detected phthalate and polychlorinated biphenyls (PCBs) at concentrations above the National Toxics Rule criteria (Ecology 1996). Both of these contaminants persist in the environment for long periods of time and have the capacity to accumulate in aquatic organisms. Bioaccumulation may lead to human health risks for those who consume fish caught in contaminated areas.

Toxic organic chemicals, lead, silver, mercury, and zinc have all been found in Duwamish River sediment samples at levels that exceed state sediment standards (Ecology 1998b).

3.4.2.4 Tributaries

Newaukum Creek

Newaukum Creek has exceeded Ecology criteria for Class A waters for fecal coliform. Water quality monitoring from July 1987 to July 1991 showed 119 exceedances of the fecal coliform criteria (Ecology 1996). Access of livestock to streams is likely the cause of these exceedances. High levels of fecal coliforms are generally associated with high levels of ammonia, which is toxic to aquatic biota. Nitrification of the ammonia decreases DO and increases nitrate levels. DO levels below Class A criteria have also been detected during the summer.

In addition to fecal coliform, the creek carries the highest levels of nitrate into the Green River of any of the tributaries that METRO has studied (Ecology 1995).

Soos Creek Basin

Water quality in the Soos Creek system has been designated as Class A by Ecology. Water quality in the basin is considered good, particularly in the eastern parts of the basin drained by Covington and Jenkins Creeks. The notable exception is recurring exceedances of fecal coliform criteria in Big Soos Creek, likely resulting from livestock access to streams (King County 1990). Temperature, DO, and mercury exceedances have also been observed between 1993 and 1995 (Ecology 1998b). Non-point sources of metals, nutrients, oil, and suspended solids are expected to increase with continued development of the basin. Areas west and north of Big Soos Creek have experienced rapid residential development. In fact, this area is the fastest growing region in King County (King County 1990).

Mill Creek Basin

Mill Creek has some of the poorest water quality measurements for DO, turbidity, and suspended solids in the Green/Duwamish Basin (METRO 1987). Class A criteria for DO, temperature, ammonia, fecal coliform, cadmium, copper, zinc, and chromium have all been exceeded numerous times since 1984 (Ecology 1996). The conditions in Mill Creek may be exacerbated by the creek's flat, slow course. However, the presence of metals in the stream can be directly attributed to development in the sub-basin.

Black River and Springbrook Creek Basin

Water quality in the Black River/Springbrook Creek Watershed is perhaps the most degraded in the lower basin. Diminished flows in the Black River, due to the diversion of the Cedar River and the loss of flows from Lake Washington in 1916, have reduced the Black River to a small creek draining flows from Mill and Springbrook Creeks. Low flows have exacerbated water quality problems in this sub-basin. The Black River receives substantial industrial and municipal wastewater discharges. Ecology Class A water quality criteria for fecal coliform and temperature have been exceeded numerous times from July 1987 to January 1992 (Ecology 1996).

Springbrook Creek has shared with Mill Creek the lowest DO levels, highest turbidity, and suspended solids of 44 sampling stations monitored by METRO (1987). Metal contamination has also been detected at two Ecology sampling locations. Cadmium, copper, lead, mercury, and zinc levels all exceeded water quality criteria. Sediment samples from the river have also failed sediment bioassays, indicating contamination levels high enough to impact aquatic organisms (Ecology 1998b).

3.5 Fishery Resources

3.5.1 Fish Habitat

The Magnuson-Stevens Act (16 USC 1801 et seq.) established a program to promote the protection of essential fish habitat (EFH) in the review of projects conducted under federal permits, licenses, or other authorities that affect or have the potential to affect such habitat. The Pacific Fishery Management Council (PFMC) (1998) defined essential fish habitat for the salmon fishery as the aquatic habitat necessary to allow for salmon production needed to support a long-term sustainable salmon fishery and salmon contributions to a healthy ecosystem. The EFH for salmon includes all those streams, lakes, ponds, wetlands, and other water bodies currently or historically accessible to salmon in Washington except areas upstream of longstanding naturally impassible barriers (i.e., natural waterfalls in existence for several hundred years). The overall goal of salmonid conservation as recommended by PFMC (1999) is to ensure that salmonid habitat requirements are met by maintaining habitat features within the natural range for the particular system.

3.5.1.1 Historic Conditions

Upper Basin

Although the upper reaches and headwaters of the Green River and its tributaries are steep, extensive spawning and rearing habitat for salmon and trout existed historically. Most of the upper basin was in late-successional forest with little human disturbance prior to the mid-1800s. The old-growth forest cover allowed infiltration of precipitation, providing groundwater flow into the streams and maintaining cold water summer flows. Large woody debris (LWD) in the Green River historically provided a diversity of pool and riffle habitats and cover, as well as nutrients to the aquatic environment to nourish the Green River food web. LWD provided significant cover for rearing salmonids. (Corps 1997a)

Middle Basin

Much of the middle basin of the Green/Duwamish River was also late successional forest with minimal human disturbance. Channel gradient in the middle basin historically was similar to the existing condition; however, channel migration was much more extensive before the placement of levees along the channel banks. The habitat in the middle basin is presumed to have been old-growth western hemlock, Sitka spruce, and western red cedar swamp along the river. Salmon spawning habitat is also presumed to have been excellent, especially for chinook and chum salmon, with an extensive complex of pools and riffles, side channels, and high concentrations of LWD. (Corps 1997a)

The mainstem below the Green River Gorge was likely used by chinook and steelhead for spawning and rearing. The middle Green River side channels and tributaries, such as Big Soos Creek and Newaukum Creek, were likely excellent spawning and rearing habitat for coho, chum, steelhead, and cutthroat trout. (Corps 1997a)

Lower Basin

The historic Duwamish Estuary in the lower basin was largely a detrital-based system and provided significant food and habitat for both terrestrial and marine organisms. Juvenile chum and chinook salmon frequently foraged in sand flat and marsh areas. These prime estuarine wetland and intertidal rearing areas for chum salmon converted high detrital carbon inputs from freshwater flows to forms usable to salmon (Simenstad et al. 1991). These forms included significant insect and crustacean populations in the marsh on which juvenile salmon fed.

Less spawning habitat was available in the lower basin because the substrate would have been largely composed of sands and finer materials. However, the extensive floodplain swamp and marsh system would have been ideal rearing habitat for most salmonid species, especially chinook. Northern pike minnow (squawfish) and long-fin smelt were also likely found in the lower Green River. (See Appendix B for scientific names of fish species.) The Duwamish Estuary was probably used extensively by juvenile fish of many species for rearing in the extensive tidal marshes and mudflats. Chum and pink salmon were reared primarily in estuaries. Many species of saltwater fish also spawned or bore live young in intertidal areas. (Corps 1997a)

3.5.1.2 Current Conditions

Two key components of habitat that are often perturbed in urban streams are water temperature and turbidity. Turbidity increases salmon egg mortality up to 85 percent when 15 to 20 percent of the gravel voids are filled with fine sediment. Water temperature affects DO levels, and salmon have specific DO requirements. Using temperatures as a surrogate measure, the following limits for all life stages are known:

- Chinook: 45° to 58°F
- Coho: 53° to 58°F
- Pink: 42° to 50°F
- Sockeye: 52° to 58°F
- Steelhead: 50° to 55°F
- Cutthroat: 49° to 55°F
- Rainbow: 54° to 66°F

The upper lethal limit for salmon is 72° to 78° F, and for trout it is 85°F (Corps 1997a). However, DO can become limiting at temperatures below these lethal limits.

Human manipulation of the natural river processes to control flooding in the basin has channelized the river, especially in the middle and lower basins; eliminated high flood flows; created uniform flows; reduced sediment supply; and further reduced supply of LWD in the river.

In-stream Habitat

Spawning habitat for salmon and trout species requires high quality gravel beds that do not have excessive fine materials filling the interstices of the gravel. Pool habitats often act as a sink for fine sediments and help maintain the quality of the gravel beds. Under natural flow conditions, floodwaters carry gravel sediments from the upper basin to the middle and lower basins, replenishing spawning gravels and depositing new gravels. Juvenile salmon and trout rear in lower velocity areas, such as pools or side channels, in both the mainstem river and smaller tributaries (Groot and Margolis 1991). Typically, the larger the fish, the larger the river or stream in which they spawn and rear (Table 3-2).

Table 3-2. Salmon and Trout Habitat Preferences

Species	Spawning Preference			Rearing Preference				
	Mainstem	Mainstem Side Channels	Tributaries	Mainstem	Mainstem Pools	Mainstem Side Channels	Tributaries	Small Tributaries
Chinook	X		X[1]	X	X	X	X	
Coho		X	X		X	X	X	X
Chum		X			X	X		
Pink	X							
Steelhead	X	X	X	X	X	X	X	
Sockeye	X	X		X				
Cutthroat			X			X	X	X

Source: information adapted from Grette & Salo, 1986; Wydoski &Whitney, 1979

[1] Chinook spawn only in larger tributaries

In-stream habitats were mapped and measured according to the McCain's (1990) Fish Habitat Relationship (FHR) methodology (Fuerstenberg et al. 1996). This method attempts to distinguish among several types of hydraulic units in stream channels and relate them to use by salmonids. The method was adapted by the Corps to allow for aerial mapping of hydraulic units in the mainstem river. Platts' pool quality index (PQI) (Platts 1987) was applied to the mapped pools. Approximately 50 percent of the habitats were field checked for accuracy. (Corps 1997a)

The habitat inventory was performed by traveling upstream from State Route 18 (SR 18) at RM 33.8 to the State Route 169 (SR 169) crossing at RM 60.3. Fast-water (riffle, run, and glide) habitats make up 82 percent of all identified habitat types. Within the fast-water habitat types, riffles and glides account for 44 percent and 53 percent respectively of the fast-water area. (Corps 1997a)

The slow-water habitats are represented by a total of 39 pools that fall predominantly into three habitat types: comer, lateral scour, and main channel pools. These types make up approximately 85 percent of the pool habitats. The slow-water category accounts for 4 percent of all habitats. (Corps 1997a)

A pool quality index (Platts 1987) was calculated for 34 of the pools; the values ranged from 1 (n=1) to 5 (n=10), averaging 3.5. The data were bi-modal, with peaks at 3 (n=11) and at 5 (n=10). The pools were notably grouped into two major areas and two less prevalent areas. The highest quality area was a 0.7-mile-long reach in the Gorge, near the public bridge (RM 50.8 to

50.1). Of the five pools in the area, four were rated at PQI 5. The other higher-quality area was at the downstream end of Flaming Geyser State Park from RM 42.8 to 42.3. Here there were four pools; three averaged a PQI value of 3.7. The PQI value for the other pool was unknown. The area from the Hamakami revetment upstream to Metzler/O'Grady Park (RM 39.6 to 36.0) had a series of 11 pools in the 3.6 miles, thus making it the longest continuous stretch of pool habitat in the middle Green River. Here the PQI was notably the lower of the nine indexed pools. The average PQI for all nine pools was 3.2, which includes two pools with a PQI rating of 5. (Corps 1997a)

Except for a small area on the bank opposite from Auburn, there is very little diversity of either side-channel or in-river habitat on the lower Green River. Much of the habitat loss on the lower Green River is due to the reduction in flow delivered to the lower reaches and to the development of extensive levee systems. The levee system has disconnected the river from its floodplain and reduced the river to a single, non-migratory channel. Much of the existing habitat that is available is in the tributaries, which may be in culverts for long reaches and behind floodgates. (Corps 1997a)

In-stream habitat was not quantified as in the middle Green Basin, due primarily to greater water depth, which did not allow sufficient light penetration through the water column. The river has limited riffled reaches and some small point bars have been developed. Much of the river is a shade of green, indicating that the water is relatively deep and undisturbed. Consequently this can be interpreted as glide or run habitat. (Corps 1997a)

Large Woody Debris

The current conifer coverage (1 percent) in the riparian zone has resulted in a reduction in the kinds and abundance of in-stream habitat types important for salmon survival. LWD is a major contributor to pool-forming processes even in large rivers (Abbe and Montgomery 1996). LWD stabilizes stream gravels, can slow flood flows, reduce scouring of the stream bed, and provide significant cover for rearing salmonids. Deep pools, gravel beds, and areas of slow water are some of the habitat types associated with LWD in streams and rivers. LWD increases the in-stream diversity of habitat (Smith and Shield 1990). LWD also influences salmon populations by accumulating areas of gravel suitable for spawning, slowing water flow, and producing cover and resting habitat for fish. Robison, Beschta, and Malanson (1993) attributed the heterogeneity in the stream they studied in Alaska in part to woody debris. Abbe and Montgomery (1996) provide compelling evidence for the role of woody debris in accreting gravel bars and stabilizing geomorphic surface so that colonization might occur.

However, the scarcity of LWD mapped in the middle Green River suggests little involvement in habitat formation; Fuerstenberg et al. (1996) found only one debris jam to be associated with a pool feature. Given the composition of the riparian zone, the age of the trees, and the lack of frequent channel movement, the recruitment rate of debris to the river should be quite low. The volume of wood found in the channel is well below undisturbed streams. Perkins (2000) suggested suitable wood densities of 0.5 meander jams and 4 bar apex jams per kilometer of the Green/Duwamish River. In less disturbed west slope Cascade streams of size similar to the Green River, loading volumes of 250 to 500 pieces per mile have been reported. The Green River load, through that portion of the river where loadings should be highest, is only 27 pieces per mile, an order of magnitude lower (Sedel et al. 1990; Fuerstenberg et al. 1996). Much of this wood is deciduous, however, and lasts only 5 to 7 years in the channel. Recruitment rates, based on best estimates of wood counts in the river, are still only about 600 cubic feet per mile per year compared with over 8,000 cubic feet per mile per year for the Quinault River. The major problem in the Green River, aside from the composition of the riparian zone, is that much wood has been removed from the river. Yet it is clear that, even in rivers the size of the Green River, LWD is the necessary structure for the formation of habitats for all species of anadromous salmonids.

Nutrient Transformations

In the Pacific Northwest, nitrogen limits forest productivity (Cornagy and Waide 1973, Silvester et al. 1982). Early successional plants (e.g., red alder and snowberry) fix large amounts of nitrogen into the soil and are among the earliest colonizers of bare ground after flood disturbance. The river helps to replenish the soil nitrogen and nutrients by initiating new cycles of vegetation succession.

The rapid decomposition of LWD at the stream-terrestrial interface hosts active microbial and invertebrate activity. This allows for rapid biological decomposition of wood and thus a quick return of nutrients to the soil (Triska and Cromack 1980). LWD provides a place for plants to germinate, thus continuing vegetative successional patterns and plant colonization. In the river itself, nutrient transformation and retention is equally important. Preliminary investigations of macro-invertebrate diversities and abundances suggest that the Green River, at least through the O'Grady reach, is somewhat lacking in nutrients. This is especially true for fine particulate organic material, also known as detritus.

Besides their importance to the commercial and recreational fisheries, anadromous fish provide a portion of the food requirement of a variety of wildlife and have a significant role in the recycling of nutrients in the ecosystem. Cedarhohm et al. (1989) determined that at least 22 species of wildlife (e.g., black bear, mink, river otter, and bald eagle) feed on salmon carcasses. Bilby et al. (1996) determined that coho salmon carcasses provided a significant percentage of the nitrogen in riparian vegetation adjacent to salmon bearing streams and significant percentages of both carbon and nitrogen in the streams' aquatic macro-invertebrates.

A study of two streams in the Snoqualmie River Basin conducted by Bilby et al. (1996) found that carcasses of returning coho salmon provided from 15 to 20 percent of the nitrogen and phosphorus found in riparian vegetation and macro-invertebrates. It has been known for some time that mass spawning species such as pink and chum salmon add considerable nutrients to Pacific Northwest rivers and their estuaries. One study on the Columbia River suggested that when a river was made inaccessible to anadromous fish (chinook in this case), trout and insect biomass rose briefly but then fell rapidly to unexpectedly low levels.

An examination of the current salmon populations and their distribution in the Green/Duwamish Basin suggests that the system may be lacking in carcasses. A complicating factor in this river, however, is the lack of debris that provides places for the carcasses to accumulate. What carcasses there are, as well as other nutrients, are likely passed quite quickly through the Green

River system and are only briefly available to the invertebrates and other animals that would feed on them.

Upper Basin

Access to fish habitat in the upper basin has been cut off from anadromous fish migrating upstream by the construction of Tacoma Diversion Dam. HHD, 3.5 miles upstream is also impassable for migrating fish. Several species of salmonids are stocked or transplanted in the upper basin. Habitat for anadromous salmonids in the upper basin is not pristine because of the extensive timber harvest activities that have occurred and the depletion of LWD from the tributaries and mainstem river. Because approximately 90 percent of the original old-growth coniferous forest has been removed, most of the riparian habitats have few coniferous trees, and LWD input is minimal. The existing riparian vegetation is largely dominated by deciduous trees and small conifers. The current condition of very young and mostly deciduous riparian forest does not significantly contribute to the LWD in the tributaries and river.

The mainstem Green River has many reaches with side channels and reasonably good fish habitat, especially from RM 84 to 77 and near Lester, where the river meanders freely in its floodplain in many locations (Corps 1997). Most of the steelhead spawning from transplants occurs in the mainstem Green River immediately above and below McCain Creek between RM 80.5 and 79.5 (USFS 1996).

Of all the tributary habitats surveyed by the USFS (1996) in the upper basin, only Twin Camps Creek and Sawmill Creek were considered to have usable fish habitat. The other tributaries surveyed were ranked poor due to lack of pools, LWD, and/or spawning gravels. The pools and spawning gravels are not maintained in the system largely because of the lack of LWD. Additionally, spawning gravels in some pools have been buried by fine sediment inputs from mass wasting or road erosion.

Middle Basin

Fish habitat in the middle Green River has been reduced from historic conditions by the construction of Tacoma Diversion Dam, HHD, levees along the river banks, logging, and development within the riparian zone. These activities have contributed to the loss of fish habitat by severely reducing recruitment of LWD, preventing sediment transport, reducing slow water habitats (e.g., pools and side channels), and inhibiting nutrient transformation/retention. These important components of fish habitat in the middle basin were studied by King County (1996) and are discussed in greater detail below.

Blomquist’s (1996) study determined that fish habitat in the middle Green River is still good in most reaches between Auburn and Tacoma Diversion Dam (RM 61to 33.8). The river retains some of its braided meandering characteristics in some locations. Blomquist’s findings were confirmed in the Fish Habitat Relationship survey conducted by King County through the middle Green River (Fuerstenberg et al. 1996). Pools make up only 18 percent of the habitat area; runs and glides account for 41 percent; and riffles for 41 percent. A further comparison with unregulated rivers such as the Willamette River (Sedell et al. 1990) suggests that pools ordinarily account for about 60 percent of the habitat area. This is much higher than the 15 to 18 percent found in the middle Green River. Two notable areas of high-quality pool habitats are located in the Green River Gorge (between RM 50.1 and 50.8) and at the downstream end of Flaming Geyser State Park (RM 42.8 to 42.3).

The major tributaries of the middle Green River are Newaukum Creek and Big Soos Creek. These tributaries have good fish habitat in many reaches, especially where the creeks are confined to a ravine or canyon and have been undisturbed. Big Soos Creek and its smaller tributaries have extensive areas of wetlands in the headwaters, which provide cool groundwater throughout the year and excellent salmon rearing habitat. The habitat is still quite good in many areas, with many pools, some LWD, and overhanging vegetation (King County 1990).

Additionally, a comprehensive fisheries assessment of the Springbrook, Mill, and Garrison Creeks was conducted from 1993 to 1995 for the City of Kent (Harza 1995). Approximately 18 miles of potential fish habitat was identified within these tributaries to the Green/Duwamish River (Harza 1995). Water quality was identified as the leading negative impact within these tributary streams; otherwise habitat, especially at transition reaches from low gradient to high gradient streams, was identified as good, resulting in the greatest fish diversity.

Lower Basin

Fish habitat in the lower basin is generally limited and significantly degraded by the armoring of the river banks and urban/industrial development. Blomquist's (1996) study of fish habitat did not inventory the lower basin in detail because it essentially found that no high-quality fish habitat existed. In-stream habitat was not quantified in the lower basin, primarily because the greater water depth did not allow sufficient light penetration through the water column. The river has limited riffled reaches and some small point bars have been developed. Blomquist considered all of the lower Green River to be in riffle/glide habitat with no pools or side channels, and essentially no LWD.

The small tributaries (e.g., Springbrook and Mill Creeks) that feed into the lower Green River from the surrounding foothills still have some areas of good-quality fish habitat. This habitat is primarily used by coho for spawning and rearing. Springbrook Creek has been dredged in its lower reaches for flood control and therefore has poor habitat in the lower miles. However, farther upstream where the streams are largely confined to steep ravines, the habitat is good, with a forested riparian zone, spawning gravels, and some LWD. The riparian zone has been significantly affected along most of these small tributaries. Stormwater runoff is increasing as impervious surfaces associated with urban development increase, and this has caused stream channel scouring in some locations.

3.5.2 Fish Use

3.5.2.1 Historic Conditions

Upper Basin

Excellent habitat for anadromous salmon and other native coldwater species is presumed to have existed in most sections of the upper Green River and its larger tributaries above Eagle Gorge.

(See Appendix B for scientific names of species.) Many of the larger tributaries (e.g., Charley Creek, Smay Creek, Gale Creek, and the North Fork) supported extensive runs of steelhead and sea-run cutthroat trout. Species that are believed to have been present in the upper basin prior to 1911 are chinook, coho, sockeye, pink, and chum salmon; steelhead, sea-run cutthroat, native char, and bull trout; resident rainbow and cutthroat trout; mountain whitefish; largescale sucker and longnose sucker; Pacific lamprey, river lamprey, and western brook lamprey; and torrent sculpin and riffle sculpin (USFS 1996).

Historic records are limited for fish run size and other information, particularly for the upper basin. Grette and Salo (1986) estimated that coho adult spawning escapement in the upper basin was 4,500 to 6,200; however, a more recent total adult run size estimate based on smolt production estimates by Washington Department of Fish and Wildlife (WDFW) (1996) is over 30,000. The run size estimate is prior to harvest, while adult escapement is after harvest is taken out. The two estimates are probably similar if considered at the escapement level. Winter steelhead escapement was estimated by Grette and Salo (1986) to be 500 to 2,600. Chinook run size numbers could not be accurately estimated, but both the fall and spring chinook runs likely used the mainstem Green River in the upper basin. WDFW estimated upper basin adult chinook run production at approximately 16,000 and adult steelhead production to be 3,500. Goetz (1996) estimated the following pristine adult run sizes: 29,147 coho; 4,410 steelhead; 1,125 cutthroat; 16,243 fall chinook; and 1,568 spring chinook. Information was very limited for spring chinook and cutthroat trout. No information was available on chum salmon, or on Dolly Varden and bull trout. Pink and sockeye salmon have been observed in low numbers in the mainstem Green River and Soos Creek (Goetz pers. comm.). The source of these fish (i.e., native or strays) is not known. No stocks of these species have been identified for the Green River (Hard et al. 1996; Gustafson et al. 1997).

Middle Basin

There are limited historical records for the middle basin fisheries and habitat conditions. The anadromous salmon and other species listed above for the upper basin were also present in the middle basin. Chapman (1981) estimated production of anadromous salmon from the mainstem Green River to below HHD in "pristine" conditions. He estimated historic adult returns for RM 66 to 28 to be 2,938 coho; 4,746 chinook; 2,116 steelhead; 114,815 chum; and 222,399 pink salmon.

Historically, a number of the streams above Tacoma Diversion Dam were used by anadromous salmonids. According to an anonymous state biologist, at least 90 percent of the spawning areas and tributaries of the Green/Duwamish Basin lie above the dam. Many of these streams (e.g., Charley Creek, Smay Creek, Gale Creek, and the North Fork) supported extensive runs of steelhead and sea-run cutthroat trout.

Lower Basin

Early historical records are also limited on fish resources of the lower Green River and Duwamish Estuary. The species identified for the upper Green River were also present in the lower Green River and Duwamish Estuary at least seasonally during adult spawning migrations and juvenile out-migrations. It is known that salmon and trout were abundant, because the

Duwamish Native Americans and early settlers operated weirs and other capture devices for salmon in the lower basin. Chapman (1981) estimated that chinook, chum, and pink salmon spawned in the lower 28 miles of the river. He estimated adult returns of 299 chinook; 6,214 chum; and 10,950 pink salmon. Spawning habitat was likely less in this reach of the river because the substrate would have largely been composed of sands and finer materials. However, the extensive floodplain swamp and marsh system would have been ideal rearing habitat for most salmon species, especially chinook. Northern pike minnow (squawfish) and long-fin smelt were probably also found in the lower Green River.

The Duwamish Estuary was also likely used extensively for juvenile fish of many species for rearing in the extensive tidal marshes and mudflats. Chum and pink salmon are known to primarily rear in estuaries. Many species of saltwater fish, such as surf smelt, Pacific herring, shiner perch, striped sea perch, pile perch, Pacific staghorn sculpin, and starry flounder spawn or bear live young in intertidal areas. Other species found spawning or resident in the estuary and Duwamish delta were likely threespine stickleback, Pacific snakeblenny, Pacific tomcod, English sole, Pacific sandlance, buffalo sculpin, walleye pollock, roughback sculpin, plainfin midshipman, tubesnout, bay pipefish, bay goby, sturgeon poacher, speckled sanddab, white sturgeon, and rainbow smelt.

3.5.2.2 Current Conditions

Over 30 fish species have been documented in the Green/Duwamish River. These fish species include both resident and anadromous stocks. Resident fish may be present in the lower river and the upper river including the reservoir area. Anadromous stocks are limited to the river system below Tacoma Diversion Dam, except where they are stocked or released in the upper basin. (Corps 1997a)

Populations of many species have declined dramatically in response to habitat loss or degradation and over fishing. Salmon and steelhead escapements to the Green River declined by 60 percent or more from 1938 to 1942 and from 1987 to 1991 (Fuerstenberg et al. 1996). Currently, runs of chinook, coho, and chum salmon, and steelhead trout to the Green/Duwamish Basin are supported by hatchery production.

Wild runs of several anadromous species use the Green/Duwamish Basin to complete their life cycle (Table 3-3). Several species, stocks, and strains of fish have entered the Green/Duwamish Basin through migration and human introductions.

The Green/Duwamish Basin fish contribute benefits to commercial catches, support tribal fisheries, and provide recreational fishing opportunities. The estimated commercial value of the anadromous fishery in the basin is $16 million (Grette and Salo 1986). Tagged Green/Duwamish Basin fish have been collected from various commercial and sport harvests in Oregon, coastal Washington, and British Columbia, in addition to within Puget Sound. Both the Muckleshoot and Suquamish Tribes harvest salmon and steelhead within the Green/Duwamish Basin and in Elliott Bay. Several species, including most anadromous stocks, are commercially exploited. The Green/Duwamish Basin is considered a primary part of the fisheries resources of Washington and ranks fourth statewide in total salmon river sport harvests. The river historically has ranked high (third in the state from 1974 to 1984) in sport steelhead catches.

Wild salmonid stocks are augmented with fish from several regional hatcheries. Hatchery fish are planted in the river from several facilities. The Green River Hatchery operated by the WDFW is the most significant facility, contributing approximately 56 percent of individuals and 43 percent of pounds of fish from 1981 to 1992. The Muckleshoot Indian Tribe Fisheries Department and the Suquamish Tribe contributed approximately 16 percent of individuals, but only 5 percent of pounds of fish planted. Chum, coho, fall chinook, summer steelhead, and winter steelhead are also released by the Muckleshoot Indian Tribe Fisheries Department and the Suquamish Tribe. Chum, fall chinook, and winter steelhead accounted for most of the production. Two other WDFW facilities contribute the bulk of the remaining salmon plants. These two facilities provided approximately 17 percent of the individuals and 49 percent of pounds of fish from 1981 to 1992. (Corps 1997a)

Central to the Green River ecosystem are the species of salmonids that inhabit the river and its tributaries. Eight species of salmonids occur in the basin: summer- and fall-run chinook, coho, chum, rainbow/steelhead, both resident and sea-run cutthroat, and native char. Pink salmon were once common in the mainstem river and several tributaries but very few have been reported there in many years. (Corps 1997a)

Table 3-3. Freshwater Life Cycle Schedule (Corps 1997)

Species	Freshwater Life Phase	J	F	M	A	M	J	J	A	S	O	N	D
Fall Chinook	Upstream Migration						[---	---	---	---	---	---]	
	Spawning								[---	---	---	---]	
	Incubation	[---	---]							[---	---	---	---]
	Juvenile Rearing	[---	---	---	---	---	---	---]					
	Juvenile Outmigration				[---	---	---	---]					
Coho	Upstream Migration	[---]							[---	---	---	---	---]
	Spawning	[---]									[---	---	---]
	Incubation	[---	---	---	---]						[---	---	---]
	Juvenile Rearing	[---	---	---	---	---	---	---	---	---	---	---	---]
	Juvenile Outmigration				[---	---	---	---]					
Chum	Upstream Migration	[---]							[---	---	---	---	---]
	Spawning	[---]									[---	---	---]
	Incubation	[---	---	---	---]						[---	---	---]
	Juvenile Rearing		[---	---	---	---	---]						
	Juvenile Outmigration		[---	---	---	---	---]						
Sea-run Cutthroat	Upstream Migration	[---]						[---	---	---	---	---	---]
	Spawning	[---	---	---]									
	Incubation		[---	---	---	---	---	---]					
	Juvenile Rearing	[---	---	---	---	---	---	---	---	---	---	---	---]
	Juvenile Outmigration			[---	---	---	---	---]					
Winter Steelhead	Upstream Migration	[---	---	---	---	---	---]					[---	---]
	Spawning	[---	---	---	---	---	---]					[---	---]
	Incubation	[---	---	---	---	---	---	---	---	---]			[---]
	Juvenile Rearing	[---	---	---	---	---	---	---	---	---	---	---	---]
	Juvenile Outmigration		[---	---	---	---	---	---]					
Summer Steelhead	Upstream Migration			[---	---	---	---	---	---	---	---]		
	Spawning	[---	---	---]									
	Incubation	[---	---	---	---	---	---]						
	Juvenile Rearing	[---	---	---	---	---	---	---	---	---	---	---	---]
	Juvenile Outmigration			[---	---	---	---	---]					

Little is known of the current status of the remaining species of salmonids once found in the Green/Duwamish Basin. Sea-run cutthroat, once plentiful in Covington Creek above Lake Sawyer, have declined over the last three decades (Fuerstenberg et al. 1996). Surveys for bull trout have been carried out in target habitats of the upper basin, but none were found. Almost nothing is known of Dolly Varden and whitefish in the river, and no surveys for the lake whitefish have been conducted in several years. Even less is known about the distribution and abundance of the other non-salmonid fish species such as suckers, sculpins, and dace.

Salmonid Diversity and Distribution

Diversity has two components: richness and abundance. Richness is defined as the number of taxa and life history variants present. Abundance is defined as the number of individuals of a given taxa present. In the case of Green River salmonids, richness is high, with eight species occupying the basin: chinook (summer and fall), coho, chum, rainbow/steelhead (summer and winter), resident and sea-run cutthroat, Dolly Varden, lake whitefish, and mountain whitefish. The possibility of a ninth species found high in the basin (bull trout) is as yet unconfirmed. Pink salmon, once common in the Green River and abundant in the White River, have been captured in Soos Creek fish traps, but the overall numbers of pink salmon have been greatly reduced throughout the Green/Duwamish Basin. The reason for their absence is not known, although loss of estuarine habitat may have been an important factor. Thus, the Green River possesses 8 species with 12 life history variations, a very diverse fauna compared to other rivers of this size in the Puget Sound region. Populations of these species are, unfortunately, quite depressed, like many other salmon populations in the Northwest. A comparison of escapement numbers provides a crude estimate of the magnitude of that decline (Table 3-4). (Corps 1997a)

Table 3-4. Comparative Escapements to the Green River

	1938 to 1942	1987 to 1991
Chinook	55,197	10,300
Chum	12,750	3,000*
Coho	36,741	12,500
Pink	1,000	0
Steelhead	4,400	1,600**

Note: Escapements of chinook and coho to the Green River hatchery were quite large in 1995. These are not reflected in these data.

* This value includes estimates for both the Keta Creek chum (about 1,600) and the wild spawning fish of the O'Grady reach and Newaukum Creek (about 1,400).

** This value is for winter steelhead only and is a simple average of the range over 1978 to 1992.

In the 1992 Salmon and Steelhead Stock Inventory (SASSI) Report, the WDFW listed eight stocks of interest on the Green River. Six stocks were considered healthy. One stock, Newaukum Creek coho, was considered depressed due to a severe decline in escapement. The status of the fall-run chum stock was unknown. However, seven of these stocks were to a great extent supported by hatchery production. Only one stock, winter-run steelhead, was described as both native and wild and is considered healthy. The remaining native stock of fall-run chum was probably extinct or at least seriously diluted by spawning with hatchery stock. Distribution of the stocks has changed dramatically as well. Between 1940 and 1995 there was a tremendous shift of stocks from the main river to tributaries, especially in the case of coho and chinook in Soos Creek.

Side channels at Metzler/O'Grady Parks (RM 40 to 37) and at Flaming Geyser State Park (RM 43) provide low-velocity spawning habitat for chum salmon during the winter, winter refuge for juvenile salmonids (especially coho, according to recent surveys), and summer rearing habitat for coho, chinook, and (only rarely) juvenile steelhead. The deeper pools of the channels are also occupied by resident cutthroat trout. Although the wetted area of the side channels falls dramatically during summer (and rises quickly during HHD releases), surveys in 1995 found pools occupied by juveniles. (Corps 1997a)

Upper Basin

The upper basin is inaccessible to anadromous salmon because of Tacoma Diversion Dam and HHD. The WDFW and the Muckleshoot Indian Tribe Fisheries Department currently plant juvenile coho and chinook salmon and steelhead trout in tributaries above HHD to rear in the upper basin. Also, the City of Tacoma traps adult steelhead at its diversion dam and transports these adults to the upper basin. Resident fish in the upper basin include rainbow and cutthroat trout, mountain whitefish, and several species of sculpin. Native char were previously known to occur in the upper basin, but recent surveys by Plum Creek Timber Company (USFS 1996) have not found any. These species are likely now extinct within the basin. Eastern brook trout have been introduced to some parts of the upper basin. Several of the lakes in the upper basin are stocked with rainbow and/or cutthroat trout, which were not previously present because most of the lakes were not accessible to fish (USFS 1996). These populations are typically not sustainable and must be stocked each year.

Middle Basin

Five major anadromous salmonid runs use the middle basin: chinook, coho, sockeye, and chum salmon, and steelhead trout. Small numbers of pink salmon and sea-run cutthroat trout may also use the middle Green River. There are three hatcheries operating in the middle Green River: WDFW's Green River and Palmer Hatcheries and the Keta Creek Hatchery operated by the Muckleshoot Indian Tribe Fisheries Department. The Green River Hatchery, which has operated since 1900, is located at the mouth of Big Soos Creek at RM 33.7. It annually stocks chinook yearlings, chinook fry, and coho yearlings. The Palmer Hatchery, operated since 1960, is located near Palmer at approximate RM 58 and annually stocks steelhead yearlings. The Keta Creek Hatchery, operated since 1977, is located on Keta (Crisp) Creek, a tributary to the Green River, at RM 40.1. It annually stocks chum fry, chinook fry, coho fry and yearlings, and steelhead yearlings (Warner and Fritz 1995). In addition, a pond complex for spring-run chinook salmon is operated at Icy Creek in the Green River Gorge. A fourth hatchery, currently in negotiations between the Muckleshoot Indian Tribe Fisheries Department and the City of Tacoma over water withdrawal, is planned for the future once permits are issued.

Recent escapements of salmonids to the middle Green River have averaged 7,600 summer/fall chinook; 1,600 summer/fall chinook in Newaukum Creek; 347 fall chum in Crisp Creek; 4,850 coho (including Big Soos Creek escapement); 5,029 coho in Newaukum Creek; 1,752 winter steelhead; and 110 summer steelhead. No data were available for chum in the mainstem Green River (WDFW and WWTIT 1994). Significant natural spawning occurs among hatchery fish because harvesters often capture wild salmon instead of the hatchery fish. In the Big Soos Creek Basin, hatchery fish are passed upstream of the hatchery to spawn naturally after hatchery escapements are met.

In recent years the majority of summer/fall chinook spawning has occurred in the mainstem over much of the middle Green River from RM 60.6 to 29.6. The reach from RM 41.5 to 33.6 appears to be particularly good. Chinook spawning also occurs in Big Soos Creek, Burns Creek, Crisp Creek, Newaukum Creek, and Spring Creek. Spawning in the tributaries is typically limited to the lower 1 to 4 miles (WDFW 1996). The majority of coho spawning has occurred in the tributaries to the Green River; however, some limited spawning occurs in the mainstem from RM 45 to 29.7. Coho spawn in many small tributaries that are unnamed, but the majority of spawning occurs in Mill Creek, Big Soos Creek, Covington Creek, Burns Creek, Crisp Creek, Newaukum Creek, Spring Creek, and the North Fork of the Green River. Chum spawning has primarily occurred in a few tributaries, with the best data from Crisp Creek. Spawning also occurs in Burns Creek, Newaukum Creek, Spring Creek, and an unnamed side channel to the Green River at RM 39.5. Pink and sockeye salmon have been observed intermittently spawning in the mainstem Green River and in Burns Creek, Newaukum Creek, and Big Soos Creek (WDFW 1996).

Lower Basin

Matsuda et al. (1968) conducted the only survey to determine all fish species present in the Duwamish Estuary and the lower Green River. They captured 30 species of fish from RM 13 in Renton to the mouth in Elliott Bay. The species found are shown in Appendix B. Warner and Fritz (1995) also captured numerous species present in the Duwamish Estuary and lower Green River up to RM 10.5 (also shown in Appendix B). Warner and Fritz (1995) captured a bull trout; Matsuda et al. (1968) captured Dolly Varden trout. It is likely both were bull trout; until recently bull trout and Dolly Varden were considered synonymous.

Spawning surveys were not conducted in the lower Green River because the substrate is not suitable for salmonid spawning. However, pink salmon generally do not migrate very far from salt water, and there may be a small population of pink salmon that spawn in the lower Green River. Escapements to the lower river tributaries are in the range of 100 fish of each species.

3.5.3 Aquatic Invertebrates

Aquatic invertebrates (insects, worms, crustaceans, and mollusks) are important to the functioning of aquatic ecosystems. As these animals feed on algae, living and dead plant material, and salmon carcasses, they take up energy and nutrients, making them available to fish that feed on the invertebrates.

Aquatic invertebrates can be described as belonging to functional feeding groups that are based on what and how these invertebrates feed. Large numbers of “scrapers” that feed on algae and associated microbes that they scrape from rock surfaces indicate an environment with stable substrate that receives enough sunshine at the substrate surface to allow development of their food source. In contrast, large numbers of “shredders” and “collector gatherers” indicate an environment with an abundance of plant material that originated outside of the stream (leaves, fir needles, and other forms of organic detritus). Fuerstenberg et al. (1996) reported some of the common taxa of aquatic invertebrates that have been reported from the Green River, their functional feeding groups, and their sensitivity.

3.5.3.1 Historic Conditions

Upper Basin

No information is available on aquatic invertebrate presence prior to 1982 for the upper basin. It is presumed that the excellent riverine habitat and water quality would have supported numerous species of invertebrates adapted to the cold, clean water of both high and low velocities. Species typically adapted to feeding on leaves, needles, and associated microbes are caddis flies, stoneflies, and craneflies. Black flies and midges may also have been common. LWD would also have played a key role in retaining organic detritus by trapping branches and leaves in pools or behind logs. Salmon carcasses also are retained by LWD to further feed the microbial and invertebrate food webs and enhance the productivity of the stream (Murphy and Meehan 1991).

Middle Basin

In the middle Green River, detrital inputs from riparian vegetation played an important, though decreasing, role. Less of the overall nutrient input to the river originated from riparian vegetation because the river was much wider here and the tree canopy did not cover the river. The increased sunlight reaching the river would lead to increased algae and aquatic plant growth in the stream. Typical species included invertebrates adapted to scraping algae and other organic matter, for example, mayflies, caddisflies, beetles, and some types of midges. Salmonids (salmon, trout, and char) prefer to eat drifting insects such as mayflies, stoneflies, craneflies, and black flies. It is likely that fish populations were limited by the amount of food drifting through (Murphy and Meehan 1991).

Lower Basin

No historic information is available about invertebrates in the lower Green River or Duwamish Estuary. However, Dethier (1990) identified common species associated with existing marine and estuarine areas in Washington that would likely represent historic conditions in the estuary.

Estuarine intertidal sand partly enclosed the marsh areas that would typically support benthic species (those living in sediment, such as clams) and epibenthic species (those living on sediment, for example crustaceans such as amphipods, Corophium sp., cumaceans; and polychaete worms). There were also significant fly and fly larvae populations on the marsh plants. The epibenthic amphipod species provided a major food resource for numerous fish and shorebirds.

In estuarine intertidal mud, found in partly enclosed and enclosed areas, the substrate was much softer than the mixed-fines substrate. It was less common to see eelgrass and its associated detrital food web in these extremely soft substrates. Benthic species (e.g., clams and worms) were common, as were epibenthic species (e.g., the crustaceans Corophium salmonis, Upogebia and Calianassa).

The Duwamish delta probably had all these habitats, particularly those habitats with fine to somewhat coarse substrate, both high and low salinity, and both high and low energy environments. There were also likely to have been significant inputs of LWD to the delta area, providing fish and wildlife habitat. This would have provided niches for an extremely diverse benthic flora and fauna.

3.5.3.2 Current Conditions

Invertebrate surveys were carried out in both side channels and the main river during 1995. The purpose of this study was to determine the richness and abundance of macroinvertebrates. Additionally, the purpose was to determine macroinvertebrate trophic and tolerance characteristics in the mainstem river and side channels near the Metzler/O'Grady and Flaming Geyser Parks. The data are presented in Corps 1997.

Upper and Middle Basin

An interesting outcome of the Green River invertebrate studies is the estimate of macroinvertebrate biomass found in the river. While many factors control abundance and richness, early data suggest that biomass in the mainstem river is approximately 45 to 60 percent of that for other rivers of comparable size and characteristics (Fuerstenberg et al. 1996).

A comparison of invertebrate functional feeding groups in the mainstem and side channels shows that the mainstem channel food web depends on material that originates within the river (algae), while side channels depend more on detritus that originates outside the river (leaves, etc.).

For the side channels, the ranking of functional feeding groups by dominance was collector/gatherers (36 percent), scrapers (18 percent), and predators (6 percent). Not all invertebrates could be categorized into functional feeding groups. This ranking reflects the predominance of worms, then midge larvae, then riffle beetles in samples collected from the side channels.

The ranking of functional feeding groups changes with seasons. In August, the overall ranking was collector/gatherers, unknowns, scrapers, and predators. During October and early November, the ranking was scrapers, collector/gatherers, unknowns, shredders, and predators. The dramatic increase in scrapers from 18 percent in the summer to 54 percent in the fall could be related to higher nutrients coming into the system during the fall rainy season, and the loss of shade from deciduous riparian vegetation thus spurring algae growth. The decomposition of plants during the fall may release nutrients that are taken up by algae (Ludwa pers. comm.).

Lower Basin

The estuarine environment is important in providing food for juvenile salmonid fish. Juvenile salmonids prey preferentially on certain species of crustaceans including amphipods (e.g., Corophium sp., Anisogammarus, Eogammarus), some species of harpacticoid copepods (e.g., Harpacticus uniremis, Tisbe sp.), cumaceans, opossum shrimp, and midges. A number of studies have characterized the benthic community on mudflats and marshes in the Duwamish Estuary. These studies can provide some insight into the suitability of these areas in providing food for juvenile salmonids as well as the overall health of these areas, and provide a baseline for comparison after restoration efforts have been made.

For example, Weitkamp and Schadt (1982) sampled the West Waterway near Harbor Island and found harpacticoid copepods to dominate most samples at moderate abundance. Stomach content analysis identified these harpacticoids as a significant food source for very small chum and pink salmon.

3.5.4 Threatened, Endangered, and Candidate Species

3.5.4.1 Chinook Salmon

Habitat Requirements and Population Status

Key habitat requirements for chinook salmon survival include adequate stream flow, gravel quality, temperature, dissolved oxygen, side channels for rearing, and estuarine food sources for juvenile rearing.

The Puget Sound Evolutionarily Significant Unit (ESU) of chinook salmon has been listed as “threatened” under the federal Endangered Species Act (ESA) (64 FR 14307). Overall abundance of chinook salmon in this ESU has declined substantially from historical levels. The types of habitat degradation that have occurred in the Green/Duwamish Basin include diking for flood control, draining and filling of freshwater and estuarine wetlands, and sedimentation from forest practices and urbanization. All have been cited as causes for the overall decline of chinook salmon in the Puget Sound ESU (50 CFR 11494).

The life history of chinook salmon in the Green/Duwamish River is illustrated in Table 3-3 (Corps 1997). Stream flow, gravel quality, and silt load all have a significant influence on the survival of developing chinook salmon eggs. Juvenile salmon rear in freshwater or in the estuary for up to 1 year before migrating to sea. Generally, chinook salmon remain at sea for 2 to 4 years before returning to freshwater to spawn. Upstream migration of adult chinook salmon in the Green/Duwamish takes place from June to November, and spawning occurs from September through December.

Known Occurrences in the Green/Duwamish River Basin

Between 1938 and 1942, chinook escapement was estimated at 55,197. By 1995, escapement had dropped to 10,300. Historical data show that in 1930, 80 percent of spawning occurred in the mainstem below Palmer and the remainder in Soos, Burns, and Newaukum Creeks. By 1995, 80 percent of spawning occurring in Soos Creek, 6 percent in Newaukum Creek, and the remainder in the mainstem. Prior to 1930, according to an anonymous state fishery biologist who wrote in 1943, 90 percent of the spawning areas and tributaries of the Green River system used to lie above Tacoma Diversion Dam (Fuerstenberg et al. 1996).

3.5.4.2 Bull Trout

Habitat Requirements and Population Status

The Puget Sound Distinct Population Segment (DPS) of bull trout is listed as a threatened species under the federal ESA. Bull trout are found in interior and some coastal drainages from northern California to southeast Alaska (Stolz and Schnell 1991). Until recently, bull trout and Dolly Varden (Salvelinus malma) were used synonymously to describe native char. These are now considered two separate species. However, because historic data do not distinguish between them, WDFW stock status data are reported as “native char” and considered to include bull trout unless it is proven otherwise. It is estimated that at least 80 distinct populations of native char exist in Washington (WDFW 1998). Bull trout in the Puget Sound region and coastal streams may include anadromous (migrating to saltwater and spawning in freshwater), fluvial (migrating within a freshwater stream), adfluvial (migrating to a lake and spawning in a stream), and resident (using only a local stream segment) populations.

Groundwater influence and proximity to cover are reported as important factors in spawning site selection. Bull trout characteristically occupy high quality habitat, often in less-disturbed portions of a drainage. Necessary key habitat features include channel stability, clean spawning substrate, abundant and complex cover, cold temperatures, and lack of barriers that inhibit movement and habitat connectivity.

Known Occurrences in the Green/Duwamish River Basin

Historically, bull trout were found in the thousands in the middle Green River when the White River was connected to the Green River (Grette and Salo 1986). Currently, the White River still supports a bull trout population, however the White River is no longer connected to the Green/Duwamish River. Their historic occurrence in the upper Green River has not been verified. The U.S. Forest Service (USFS) conducted recent surveys in the upper basin and several tributaries (e.g., Sunday Creek, Pioneer Creek) and found no evidence of bull trout. Plum Creek Timber Company has also completed surveys in other upper Green River tributaries with no verification of bull trout presence (Plum Creek 1996). The habitat in these areas was considered somewhat degraded due to past timber harvests. Stream temperatures in the survey area may also be warmer than temperatures required by bull trout in the late summer (Goetz 1989, 1994). Bull trout were last reported in the Green River in 1964 and in the Duwamish River in 1994.

3.5.4.3 Coho Salmon

Habitat Requirements and Population Status

Coho salmon typically exhibit a three-year life cycle. Adults begin migration into freshwater in late summer or early fall. Spawning occurs from October to January. Eggs incubate in gravel interstices until spring. Juvenile coho will typically spend 12 to 18 months rearing in freshwater before migrating to saltwater in spring or early summer. Puget Sound coho migrate to the Pacific Ocean and generally return to spawn at 3 years of age. The eggs and developing alevins depend on cool, oxygen-rich water and clean gravel. Juvenile coho (fry) typically rear in low-velocity side channels and other backwater areas with extensive cover. Because some life stage of coho are typically in a stream all year, this species requires maintenance of cool, well-oxygenated water, even during the summer months.

The Puget Sound Coho ESU is a candidate for listing under the ESA. As a candidate species, no federal protection is in place, however, this species is under consideration for listing. From 1965 to 1993, Green River coho run size has not changed significantly (Weitkamp et al. 1995). Because most years in this time period had stable escapement rates, the stock status was considered healthy by WDFW in 1994 (WDFW 1994).

Known Occurrences in the Green/Duwamish River Basin

Coho escapement between 1938 and 1942 was estimated to be 36,741. During 1987 to 1991 the number had dropped to less than 12,500 or about one-third. As with chinook salmon, the distribution of spawning coho has changed since 1930. In 1930, 52 percent of spawning took place in the mainstem Green River, 33 percent were in Soos Creek, 11 percent in Newaukum Creek, and 4 percent in Burns Creek. In 1995, 10 percent spawned in the mainstem, 85 percent spawned in Soos Creek, and 5 percent spawned in Newaukum Creek. (Corps 1997). Between 1967 and 1991 escapement ranged from a high of 12,500 in 1968 to a low of 700 in 1991.

3.5.4.4 Anadromous Cutthroat Trout

Habitat Requirements and Population Status

Anadromous, or sea-run, cutthroat trout are widespread through Washington west of the Cascade mountain range and are typically found in lower elevation and lower gradient streams below barriers to passage. Adults migrate to freshwater in summer and spawn in February or March. Fry emerge from the gravel substrate by mid-July, and juveniles will rear in freshwater for an average of 2 years before migrating to Puget Sound. Many stocks are believed to migrate only as far as estuarine areas as adults, and these areas can be important to their survival (Leider 1997).

Freshwater habitat impacts affecting sea-run cutthroat are generally those affecting water quality (temperature, oxygen, turbidity) and quantity, siltation in spawning substrates, and loss of cover and woody debris (Leider 1997 after Meehan 1991). In the estuarine or marine environment, the loss of habitat area and productivity are typically the most important impacts.

The Puget Sound anadromous cutthroat trout ESU is a candidate for listing under the ESA. As a candidate species, no federal protection is in place, however, this species is under consideration for listing. Although data have been collected on sea-run cutthroat trout populations, consistent records have not been kept over a long enough time period to assess the status of these stocks. In general, North Puget Sound stocks appear to be doing well (Leider 1997). The status of sea-run cutthroat trout has not been documented for the Green/Duwamish Basin. While the run size data for this species in the Green/Duwamish Basin is not available, there is some use by sea-run cutthroat as well as resident trout (Snyder pers. comm.).

Known Occurrences in the Green/Duwamish River Basin

Sea-run and resident cutthroat trout use the Green/Duwamish Basin, however, run size and stock status data are not available (Snyder pers. comm.).

3.6 Botanical Resources

3.6.1 Vegetation

3.6.1.1 Historic Conditions

The Puget Sound region was historically heavily vegetated by evergreen coniferous trees with an understory of various shrubs, ferns, and herbs. The forests dominated most locations in western Washington from sea-level up to nearly 6,000 feet. The native vegetation is adapted to the cool, moist climate dominated by Pacific maritime weather patterns. This vegetation is also adapted to periodic fires and other local disturbances such as flooding and the seasonal high water table (Kruckeberg 1991).

The Green/Duwamish River Basin was subject to more frequent historic fires than other western Washington basins. This was most likely due to the drier nature of portions of the basin. In the natural fire regime, snags would remain in burned-over areas and provide habitat for many bird species. Also, under the natural regime, downed trees remained in place and provided nutrients and stability to the soils. After construction of the railroad in the 1880s, numerous fires were started by sparks emitted from the trains and burned the main valley and the south side of the basin. Localized events (e.g., avalanches, windthrow, and floods) periodically opened small gaps in the forest, typically less than 100 acres. These events would be succeeded by meadows dominated by grasses, ferns, and flowering annuals such as fireweed. Within a few years, young tree seedlings would begin to dominate the meadows, typically red alder, bigleaf maple, willows, and Douglas-fir. (Corps 1997a)

Upper Basin

The upper portion of the Green/Duwamish Basin ranges in elevation from approximately 1,000 to nearly 6,000 feet. The upper basin is lower than most basins arising in the western Cascade Range and hence, even the highest reaches of the basin were forested if there was suitable soil. Four vegetation zones were present historically in the upper basin: western hemlock zone, Pacific silver fir zone, mountain hemlock zone, and subalpine fir zone.

Most of the upper basin was in the western hemlock zone. At elevations above 3,000 feet, Pacific silver fir was the dominant climax species, though western hemlock and western red cedar were also significant. At elevations above 5,000 feet, mountain hemlock was the dominant climax species. Approaching 6,000 feet elevation, subalpine fir was the dominant climax species. Because of the overall lower elevations in the upper basin compared to other basins, there was very little terrain in the Green/Duwamish Basin for either mountain hemlock or subalpine fir dominance.

Middle Basin

The elevation of the middle basin ranges from approximately 200 to 1,000 feet. The entire middle basin was within the western hemlock vegetation zone. Little historic site-specific information is available; however, it is likely that western hemlock forest occupied the majority of the middle basin. Soils found in this area were generally typical of soils formed under coniferous forest canopy. Douglas-fir (dry areas) and western red cedar (wet areas) may also have composed a significant part of the overstory depending on moisture. Bigleaf maple and Pacific madrone were also prominent in this lowland forest community. Typical understory shrubs included vine maple, red huckleberry, devil's club, salal, and Cascade Oregon grape. Typical herbs included sword fern, deer fern, evergreen violet, western trillium, and false lily of the valley (Kruckeberg 1991). From Auburn to Kent, the floodplain was most likely dominated by Sitka spruce and western red cedar swamps, with open wetland areas (Shapiro 1990). Areas that had not been scoured by the river for many years (less than 100 years) would develop into Sitka spruce and western red cedar swamps.

Lower Basin

The lower basin in historic times was a flat, meandering river characterized by a floodplain and wetland complex. This floodplain and wetland complex was similar to the Sitka spruce and western red cedar swamps found in the middle basin.

3.6.1.2 Current Conditions

The Green/Duwamish Basin falls within the Southern Washington Cascade Province, a physiographic categorization that extends south from Snoqualmie Pass to the Columbia River. Within this province, the climax forest zone type for the Green River is the Tsuga heterophylla zone (Franklin and Dyrness 1973). In this zone, Douglas-fir is the subclimax species followed by the climax species, western hemlock and western red cedar. Red alder, bigleaf maple, and golden chestnut are the most widespread hardwood species. Along major waterways, red alder, black cottonwood, Oregon ash, and big leaf maple, are most common (Franklin and Dyrness 1973). Logging, agriculture, and urbanization have dramatically altered the species composition, maturity, and density of vegetation throughout the basin.

Red alder is the most widely distributed early seral tree species on wet sites in coast ranges. In stands of red alder, the understory shrub layer is most frequently dominated by salmonberry. Other species characteristic of seral communities on moist sites include vine maple and buck lotus. A later seral community on moist sites is composed of Douglas-fir, vine maple, and sword fern. The climax association is western hemlock and sword fern. Western hemlock is shade tolerant and capable of reproducing under a forest canopy whereas Douglas-fir is not. The successional pattern applicable to the Green/Duwamish Basin that is suggested by these studies is shown in Table 3-5.

Table 3-5. Successional Pattern for the Green/Duwamish River Basin (Corps 1997a)

Pioneer Species (colonizers)	(variable)	(100 to 150 years)	Climax Species (400 to 600 years)
Red alder Willow Black Cottonwood Bigleaf Maple	Douglas-fir	Western Hemlock Western Red Cedar Douglas-fir	Western Hemlock Western Red Cedar

Currently, the foothills and mountainous areas of the basin provide the largest blocks of conifer forest to be found in the basin. Virtually all of this is second-growth forest. Though significantly altered in the middle basin, numerous wetlands occur in the flatter areas adjacent to the river. Except for the Mill Creek area, most wetlands in the lower basin were converted to farmland, and then to urban land many years ago.

Upper Basin

Plant association groups that dominate the basin are western hemlock or Douglas-fir with an understory of swordfern, salal, and Oregon grape. In higher elevations there are also significant components of Pacific silver fir, with an understory of Alaska huckleberry. Figure 3-5 shows the current vegetation and land use in the upper basin.

Timber harvest has occurred in the upper basin since the late 1800s. In the peak timber years (1980s), approximately 15 million board feet of timber were harvested per decade on the USFS lands alone (Johnson pers. comm.). Significant portions of the upper basin are in a "checkerboard" ownership pattern with a mix of USFS lands and private timber companies. Private lands were largely harvested in the 1960s and 1970s, and extensive replanting of young Douglas-fir occurred in many areas. Current harvesting generally occurs in second-growth areas.

Harvested forest areas are considered hydrologically disturbed until the canopy cover exceeds 70 percent. For western hemlock and Douglas-fir, this typically requires a minimum of 20 years of growth. Currently, the upper basin has a high level of disturbance, with 20 to 60 percent of the upper basin considered hydrologically disturbed. Hydrologically disturbed areas are subject to increased snowmelt during precipitation events and subsequently higher stream flows. Over the last 150 years, there has been a loss through harvest and fires of approximately 90 percent of the old-growth habitat that formerly existed. The old-growth patches remaining are small (less than 1,000 acres), fragmented, and generally located near the headwaters of tributaries in fairly inaccessible locations (USFS 1996). Nearly all the western hemlock old-growth has been harvested; however, some Pacific silver fir and mountain hemlock old-growth remains. These remaining old-growth patches are typically surrounded by roads and open-cut areas. The USFS (1996) estimates that greater than 80 percent of the forest in the upper basin is 1 to 100 years old, dominated by Douglas-fir and deciduous species, and generally without snags.

Middle Basin

The middle basin is characterized by open hills and flat lands of glacial and lacustrine deposits. The few forested slopes in this region are dominated by Douglas-fir, western hemlock, and western red cedar. Deciduous trees dominate the area (e.g., black cottonwood, Oregon ash, red alder, and willow). Logging, agriculture, and urbanization in this portion of the basin have altered species composition, age,, and density of the vegetation. Large areas of upland grasses (i.e., pastures) and active corn and cabbage crop production are also common. Figure 3-6 shows the current vegetation and land use in the middle basin.

The middle basin is largely rural residential and agricultural land uses with several large state parks and commercial timberlands on the upland hills. Essentially all of the middle basin has been cleared in the last 100 years, and most forested areas are second-growth or third-growth deciduous or a mix of deciduous and coniferous forest. Deciduous forested areas are predominantly bigleaf maple, red alder, and black cottonwood. Western red cedar and Douglas-fir may be mixed with these deciduous trees in places. Private timberlands are typically managed for the production of Douglas-fir. Red alder, black cottonwood, and willows are found in the wetter areas. (Corps 1997a)

In the parks, such as Flaming Geyser State Park, the vegetation is more natural, albeit second-growth. Typical species include black cottonwoods, alders, and Douglas-fir, with some large western red cedar. The understory is typically composed of salmonberry, ocean spray, and snowberry.

Lower Basin

Until the early 1970s, most of the lower basin was in agricultural production. There are approximately 2,000 acres of agricultural land remaining in the middle and lower basins. Timber harvest and residential development have occurred on many of the upland slopes. Today many of the upland slopes have a mixed deciduous/conifer second-growth forest dominated by Douglas-fir and bigleaf maple. Figure 3-7 shows the current vegetation and land use in the lower basin.

The lower basin including the Duwamish Estuary has been heavily developed for industrial and residential purposes. All of the former river channels have been channelized into one major channel, which is dredged up to the Turning Basin at RM 6.2 to maintain a depth of approximately 12 feet. From Auburn to Kent, the floodplain has been completely cleared of forest and many of the wetlands have been filled or drained.

The existing vegetation in the Duwamish Estuary is limited due to the extensive industrial development that filled most of the intertidal and freshwater tidal marshes and swamps. In the remnant intertidal areas, the marsh communities are dominated by Lyngby sedge, saltgrass, Baltic rush, brass buttons, and hardstem bulrush. The invasive reed canarygrass dominates the marsh plant community in at least two locations. On upland sites, the vegetation is dominated by weedy species such as Scot’s broom, Himalayan blackberry, and tansy ragwort. A few sites have been planted with native vegetation in an attempt to restore habitat to the waterway and these sites are dominated by willows, alders, cottonwood, and shrubs such as red-flowering currant (Corps 1995a).

3.6.2 Wetlands and Riparian Areas

3.6.2.1 Historic Conditions

The limited information on the historic wetlands indicates wetlands were probably associated with persistent natural dams, side channels, and topographic depressions. In locations where flow was significantly reduced (i.e., beaver dams) or isolated from the main channel flow, in the case of side channels or oxbows, wetland communities could develop. Open depression areas where a flood event or windthrow had cleared the overstory vegetation could also develop into a wetland if the necessary hydrologic conditions existed.

Riparian vegetation historically consisted of mature coniferous and mixed coniferous and deciduous trees. During large historic flood events, flood waters would knock some of these trees into the river where they would become LWD. The LWD would block flows in the river, contributing to the formation of eddies, pools, side channels, and wetlands.

In riparian areas, flood flows and the erosion/deposition of sediment and debris often kept the forest from proceeding to climax communities. These floodplain areas were typically dominated by willows, alders, and cottonwood. These species are adapted to a high water table and frequent flooding. They also grew quickly after disturbance. Coniferous species occurred on floodplain terraces, but age was often limited by river meandering (i.e., approximately 100 years). Old-growth likely only occurred in the floodplain when protected by very large accumulations of LWD or rock.

Historical information about vegetation was researched by King County as a reference for interpretation of current conditions of vegetation in the riparian zone. Information was sought for the 1930s, pre-1900s, and pre-1850s to identify conditions at benchmark periods through time.

The King County study defined the middle basin (hereafter called the KC Middle Basin) as extending from RM 45.7 to 33.78 and the lower basin (hereafter called the KC Lower Basin) as extending from RM 33.78 to the mouth of the river. In this study, data from 1936 photos of the river were compared with data from the 1993 photos. Four categories of riparian condition were defined: industrial and bareground, residential and few trees, trees and undeveloped, and shrubbery and farmland. Results of the analysis are shown in Table 3-6.

Table 3-6. 1936 to 1993 Comparison of Green/Duwamish River Vegetation

Category	Lower Green 1936	Lower Green 1993	Middle Green 1936	Middle Green 1993
Shrubs/farms	77%	36%	16%	29%
Trees/undeveloped	8%	16%	85%	67%
Residential	3%	13%	0%	0%
Industrial	12%	36%	0%	0%

The overall tree coverage along the full length of the river decreased about 10 percent from 1936 to 1993. From 1936 to the present time, the decline of forest land cover has continued in the KC Middle Basin, but in the KC Lower Basin, forest land cover has increased. Tree coverage along the KC Middle Basin was 85 percent in 1936, declining to 67 percent by 1993. Even as early as 1936, the KC Lower Basin had few trees along the river's edge (8 percent). Based on these data, the KC Lower Basin had an increase in tree cover from8 percent to 16 percent from 1936 to 1993.

The Duwamish Estuary was also a flat, meandering river, but with tidal influence. The Duwamish Estuary was an extensive marsh of over 4,000 acres. This transitioned into a brackish marsh, saltmarsh, and mudflats on the farthest edges of the delta. The main channels were largely unvegetated mudflats and sandflats. Patches of eelgrass were likely present in the saline areas.
A classification of typical saltwater communities by Dethier (1990) states that American three-

square bulrush is the characteristic plant species in bay and delta areas. Other marsh communities were also likely present because of the range of substrate types and current energies. Such communities included low marsh species such as saltgrass, seaside arrowgrass, Lyngby's sedge, and pickleweed. High marsh species included tufted hairgrass, Baltic rush, Pacific silverweed, and red fescue.

3.6.2.2 Current Conditions

The 1996 King County study indicated that conifer tree vegetation has been virtually eliminated and replaced by pavement, deciduous trees, and shrubs in the middle and lower basins. The total vegetation acreage (i.e., deciduous, conifer, and mixed trees) now is 28 percent of the length of the river and 36 percent along the river's edge compared to almost 100 percent coverage in a presettlement state. Figure 3-8 shows the location of sensitive habitats, including wetlands and riparian, within the basin.

Deciduous trees and shrubs form the largest categories of vegetation along the river's edge. About 1 percent of the riparian zone acreage (defined as the area 300 feet on either side of the river) and 1 percent of the lineal footage is conifer vegetation. In terms of acreage, buildings and pavement cover 37 percent of the land surface in the riparian zone. Intertidal zone habitat is dramatically reduced from historical times. Less than 1 percent of the acreage of the riparian zone is intertidal habitat. No estimates of intertidal vegetation were made for the King County report.

The vegetation that now exists in the riparian zone is patchy and narrow. This reduction in riparian vegetation has reduced the corridor function of the riparian zone for wildlife and plants, and has reduced connectivity to upland seed sources. Currently, only a few patches of conifer even extend the width of the 300-foot riparian zone set for this study. The reduction in the riparian zone has also reduced the amount of woody debris suitable for LWD formation (Fuerstenberg et al. 1996).

LWD was inventoried by King County for the reach from just east of Auburn, at RM 34, to just east of Flaming Geyser State Park (RM 47) using the 1994 Middle Green River aerial photographs and comparing the LWD estimates from 1936 aerial photographs (Fuerstenberg et al. 1996). The photographic count of LWD in the river today shows a total of 376 pieces of wood (29.6 pieces per mile) visible either in the channel or available to the river on bars (Figure 3-9). The vast majority of the observed wood was deciduous. Three log jams were apparent in the 1994 photos. The first at RM 38.6 spanned the width of the river, contained nine visible pieces of LWD, and was the only jam in the study reach associated with a pool feature. The second jam, also containing nine pieces of LWD, was observed at the entrance to a side channel at Metzler/O'Grady Park at RM 40. The third log jam contained 10 to 12 pieces of LWD, and was located at the head of a right bank side channel in Flaming Geyser State Park (RM 43.7).

Upper Basin

The upper basin wetlands and riparian zones have been significantly affected by logging practices. A significant portion of the wetlands have roads either through them or adjacent to them. Significant wetlands occur along Smay, West Fork Smay, Friday, Tacoma, and West Creeks and the North Fork Green River. Wetlands associated with West Creek, Tacoma Pass headwaters, and the confluence of the West, Snow, and East Creeks have been identified as biodiversity “hotspots” (Corps 1997). Numerous wetlands occur on the floodplain adjacent to the river in the flatter portions of the basin above the dam.

Middle Basin

Numerous lakes, ponds, and wetland areas occur in the upland forests of the middle basin. However, many of the lakeshores are in various stages of residential development. Much of the valley floor in the middle basin consists of open fields, either as cropland, pasture, or open areas on industrial properties. Rush and sedge-dominated wetlands occur in the wetter meadows. Upstream of SR 18, the middle portion of the Green River flows through farmlands, pastures, and park lands. The riparian zone is primarily deciduous or mixed forest with pavement, buildings, or levees. Deciduous trees are the major vegetation type, covering 59 percent of the land bordering the river and 40 percent of the riparian zone acreage. The second largest land cover type classified as “other” includes pavement, buildings, and bare ground. “Other” accounts for 24 percent of the acreage and 20 percent of the footage along the river. Shrub cover is 6 percent of the total acreage of the riparian zone. Levees and bank armoring are dominated by grasses, weedy herbaceous species, and Himalayan blackberry.

Lower Basin

Approximately 41 percent of the riparian vegetation coverage of the KC Lower Basin is pavement. Next to the water’s edge, pavement as land cover drops to 20 percent. Deciduous trees compose 18 percent of the acreage and 26 percent of the footage next to the river.

Today approximately 45 acres of intertidal flat and tidal marsh habitat remain in the entire Duwamish Estuary, less than 3 percent of the original area (Blomberg et al., 1988). Other than Kellogg Island, intertidal habitat is widely dispersed in small patches. Small areas of marsh dominated by sedges and unvegetated intertidal beaches are all that remain of the once expansive wetlands.

Because of extensive agricultural and industrial development along the lower river, most of the riparian overstory has been removed. In a few locations, willows, alders, and cottonwoods still occur along the river. However, in general, the riparian vegetation consists of invasive exotic species such as reed canarygrass and Himalayan blackberry or ornamentals associated with residential and industrial development.

3.6.3 Threatened, Endangered, and Candidate Species

The state and federal agencies have provided letters listing rare plant species and high-quality wetlands and habitats within the Green/Duwamish River Basin (see Appendix C). One federally listed species, the marsh sandwort, could potentially but is unlikely to occur in wetlands near proposed restoration areas; the species is possibly extirpated from the area.

3.7 Wildlife Resources

3.7.1 Wildlife Habitat and Use

3.7.1.1 Historic Conditions

The historic basin was composed of large patches of contiguous forested habitats and wetlands. Unique features such as subalpine areas, cliffs, talus slopes, streams, gorges, and riparian vegetation added to the variety of habitats in the area. (Corps 1997a)

Upper Basin

Historic vegetation was generally composed of large patches of contiguous coniferous forest habitat in various seral stages. These forests likely had a diversity of conditions within them and large quantities of snags and coarse woody debris. The major form of disturbance that shaped vegetation conditions in the basin was periodic natural fire. Large fires have burned vast areas of western Washington at approximately 200-year intervals (USFS 1996). Such fires would have burned at varying intensities leaving frequent unburned patches as well as large quantities of snags and coarse woody debris both scattered and in patches. These fires also left large areas of forest untouched in older seral stages. It is estimated that at any given time 15 to 20 percent of the landscape consisted of old-growth, and up to an additional 30 percent was late-seral forest (USFS 1996).

Species associated with old-growth and late-seral contiguous habitats, such as marbled murrelets and spotted owls, would likely have been found within the upper basin. Deer and elk populations also thrived, as did mountain goats, raccoons, squirrels, muskrats, hares, and numerous other small mammal species. The abundance of prey species supported an abundance of mammal predators including black bear, grizzly bear, gray wolf, cougar, coyote, and bobcat. Wolverine occurred in the higher elevations.

Middle Basin

Prior to Euro-American settlement, the basin was most likely in pristine condition and the extensive wetlands that once existed in the area were unaltered. Some of the valley area supported ground cover consisting of rushes, sedges, or grasses. The higher ground was covered with thickets of maple, cottonwood, ash, and alder, with scattered fir, cedar, and spruce. (Corps 1997a)

The first notable changes within the basin probably took place in the 1850s, when forest lands were cleared and converted to open land for farming. By the 1970s, industrial, commercial, and residential growth intensified in the middle basin. Pastures were drained and agricultural fields began to be filled and developed. Remaining wetland systems were reduced in size and confined by new roads and developments (Shapiro 1990).

Presumably, abundant wildlife existed in the area, based on the high incidence of wetland habitats and forested areas. The wetland habitat supported diverse plant and insect life as well as numerous species of amphibians. Waterfowl used these areas during the fall and winter. The wetland marshes provided valuable breeding locations for ducks, rails, and numerous songbirds. This area historically supported more abundant populations of large predators than are present today. (Corps 1997a) Old-growth and late-successional associated species would also have been abundant in the older upland forests.

Lower Basin

The broad plain of the lower basin historically consisted of extensive marshes (saltwater and brackish), freshwater wetlands, and riparian habitats. Prior to the 1900s, the Duwamish River Estuary was composed of a variety of extensive wetland and near-shore habitats. Higher intertidal areas were inundated by the highest spring tides and flood events and supported forested wetlands or swamps. In lower, more regularly inundated portions of the Duwamish River Estuary, tidal marshes once predominated. It is estimated that 1,270 acres of intertidal marsh existed in the lower Duwamish prior to settlement (Blomberg et al. 1988). The estuarine habitat types would have provided niches for a highly diverse benthic flora and fauna.

Wetlands provided the most productive wildlife habitat of all land within the lower basin. The diversity of wetland habitats in this area provided critical biological resources of food, water, and cover for a diversity of wildlife. Recent studies have correlated bird species use with wetland habitat complexity (Wallin et al. 1995). Wetlands with the highest number of plant communities present had the highest bird use as measured by bird species richness, plant species richness, and bird species breeding rates (Wallin et al. 1995). The expanses of marsh habitat dominated by eelgrass and marsh species were widely used by birds such as great blue herons, mergansers, western grebes, and brant. In unvegetated areas crows, gulls, killdeer, mallards, and pintails foraged for benthic and epibenthic invertebrates.

Historically, bird populations using the lower basin included Canada geese, mallards, gadwalls, green-winged teal, Northern shoveler, canvasback, scaup, ruddy ducks, American coot, western grebes, pintails, American pigeon, Barrow's goldeneye, bufflehead, scoters, and mergansers (Canning et al. 1979).

No historic mammal records exist for the Duwamish Estuary. However, it is likely that voles, muskrats, rabbits, deer, and rodents were resident in the area. Predators such as coyotes, wolves, and bears likely inhabited the area seasonally (Corps 1995a).

3.7.1.2 Current Conditions

Currently, the foothill and mountainous areas provide the largest blocks of coniferous forest to be found in the basin, and virtually all of this is second-growth forest. Coniferous forest habitat in the valley floor of the middle and lower basin has been nearly eliminated by agriculture and urban development. Similarly, wetland and riparian habitats have been virtually eliminated below Auburn, although some still exist in the upper basin and the upper portion of the middle basin. In the Duwamish Estuary, only about 31 percent of the original wetland and intertidal habitats remain (Corps 1996).

Existing forest patch sizes are small and medium (less than 1,000 acres) at mid and low elevations and small (less than 60 acres) at high elevations. This limits the current use of the area for species with large home ranges. These species may not be able to use multiple patches of fragmented habitat to meet their life history requirements.

Fragmentation and the resulting lack of connectivity adversely affect forest interior associated species in several ways.

Roads fragment forested habitats by creating linear clearings that introduce edge. Road densities in the upper basin were measured at approximately 2.5 miles/square mile (USFS 1996). To minimize disturbance, wildlife managers generally recommend that road densities not exceed 1 mile per square mile (Frederick 1991; Tucker et al. 1990). Increased predation as a result of high road densities can be significant for some species. Rich et al. (1994) found that fragmentation effects occurred with clearing widths as small as 24 feet by attracting cowbirds and nest predators to forest interiors. The presence of travel corridors is important in facilitating the movement of species across the landscape. The amount and arrangement of connective corridors today are much more limiting to wildlife than those present under a natural fire regime, where connective corridors would have been left in large blocks (USFS 1996). There may, however, be some suitable habitat for travel corridors in the lower elevations of the upper basin where railroad-era logged and burned forest have grown into the closed immature stage (USFS 1996).

Upper Basin

Habitat in the upper basin consists of coniferous forests in early to mid-seral stages and clearcut areas in various stages of regeneration from previous logging operations. Only about 10 percent of the original old-growth forest habitat in the upper basin remains. Wildlife species that depend on old-growth forest are likely restricted to individual patches, thus decreasing their likelihood of genetic mixing and survival. The old-growth patches are small and extraordinarily isolated at the headwaters of some tributaries. The USFS (1996) identified biodiversity “hot spots” in existing small patches of old-growth forest. These locations are unique in the upper basin for their diversity of species associated with old-growth forest and include:

- A 50-acre Douglas-fir climax stand at Intake Creek
- A 50-acre western hemlock old-growth stand at Twin Camps Creek
- A 100-acre western hemlock old-growth stand at East Creek

Continued fragmentation and checkerboard ownership issues in the upper basin will be problematic to many native species that require contiguous habitat for travel and dispersal. The coniferous forests of the upper basin provide habitat for a variety of animals. Due to its “closed” status as the City of Tacoma’s watershed, this area is prime habitat for large mammals such as elk, mountain goat, black-tailed deer, mule deer, black bear, and cougar. Elk are most commonly seen in the scattered meadows of abandoned farms. The large number of herbivores in the upper basin has resulted in a significant mountain lion population, reported to be one of the highest population densities in the United States. Black bears are also relatively common in the upper basin, and mountain goats occur in the higher elevations. (Corps 1997a) See Figure 3-8 for locations of some of these wildlife species in the basin.

Furbearers in the upper basin include beaver, mink, muskrat, weasels, raccoon, and snowshoe hare. Pika have also been observed on the rock slopes near the railroad tracks. Small mammals such as Townsend chipmunk, chickaree, redback voles, and deer mice are also common. Several amphibian species occur in the basin and include Cascade frogs and red-legged frogs. (Corps 1997a)

Great blue heron, Canada goose, mallard, green-winged teal, wood duck, harlequin duck, hooded mergansers, and common mergansers may nest within the upper basin. Breeding harlequin ducks have been observed near Howard Hanson Dam (HHD). Common loons have also been documented within the Howard Hanson Reservoir. During the winter, common goldeneye, ring-necked duck, and bufflehead use the reservoir. Belted kingfishers nest along the reservoir. Raptors occurring in the upper basin include bald eagles, red-tailed hawk, Cooper's hawk, sharp-shinned hawk, northern harrier, osprey, and several owl species. A wide variety of passerine birds also occur in the upper basin, including warblers, woodpeckers, and flycatchers. (Corps 1997a)

Middle Basin

Mixed forests of deciduous and evergreen trees line the steep sides of the middle basin and provide habitat for a variety of birds and small mammals. The upland forests of the middle basin are dotted with numerous lakes, ponds, and wetland areas.

The fragmentation of habitat and the decrease in diversity of plant species within the remaining habitats have directly affected the diversity of wildlife species in the middle basin. In addition, invasive non-native species shade and crowd native vegetation and provide habitat for generalist wildlife species and non-native animal species that outcompete native wildlife.

Currently, the riparian habitat of the middle basin occurs mostly around ponds and swamps. Riparian habitat is known to produce a relatively high diversity of wildlife as a result of its productivity and vegetative complexity. The remaining riparian habitat is a valuable wildlife resource to this area, but has been fragmented by agricultural use, road building, and urbanization. Only a few patches of coniferous forest even extend the width of the riparian zone. (Corps 1997a)

Bird diversity is high in the middle basin. Many small mammals (e.g., foxes, skunks, weasels, and squirrels) use the dense understories of some of the forested stands. Small streams and sloughs meander through the pasture and upland habitats, providing habitat for many species of insects and for amphibians including red-legged frogs, Pacific tree frogs, salamanders, and toads. Reptilian fauna is not diverse, but several species of snakes and lizards occur here. (Corps 1997a) See Figure 3-8 for locations of some of these wildlife species in the basin.

Lower Basin

The lower basin and Duwamish Estuary are now heavily developed for industrial and residential purposes. The remaining riparian, wetland, and estuarine habitats in the lower basin are used by a variety of birds and small mammals. However, continued development in the lower basin is rapidly reducing this habitat. The remaining marsh habitats provide exceptional areas for wildlife because of their high biological productivity.

Flood storage areas primarily covered with dead and living willows are found in the lower basin, often contiguous to or intergrading with the marshes. These areas are valued to some extent as breeding and feeding areas for waterfowl and songbirds, but are used much less frequently than the marshes. Waterfowl also use ponds throughout the lower basin, either in the form of wet pastures that have year-round ponds, inactive sewage ponds in the Auburn area, or ponds that have formed in the pits associated with previous gravel operations. Generally, shallow ponds with gradual banks are most productive and are the best areas for wildlife. More than 10,000 waterfowl presently use the fields, ponds, and marshes near Kent, Renton, and Auburn for feeding and resting. (Corps 1997a)

Mammal usage of the Duwamish Estuary has been limited because the site is surrounded by industrial development and roads. Mammals inhabiting Kellogg Island and the estuary include raccoon, Townsend voles, muskrats, and Norway rats. Voles and muskrats likely consume fleshy plant material from the high and low marsh areas. Raccoons consume fish, turtles, small mammals, birds, eggs, insects, and plant material, especially berries. California sea lion, harbor seals, and river otters have been observed in the Duwamish Estuary. These species consume small fish, eggs, and invertebrates in the shallow and subtidal waters (Ingles 1965). See Figure 3-8 for locations of some of these wildlife species in the basin.

3.7.2 Endangered, Threatened, and Proposed Species

In January 2000, the U.S. Fish and Wildlife Service (USFWS) identified five federally listed animal species and two candidate species (see Appendix C). Canada lynx was recently listed as threatened as of March 24, 2000 (58 FR 16052). Although grizzly bear was not identified in the USFWS letter, it is addressed here since usable habitat exists and sightings have occurred near the project vicinity.

The listed endangered and threatened species include the bald eagle, gray wolf, marbled murrelet, northern spotted owl, bull trout, and Canada lynx. The peregrine falcon was delisted from its former standing as an endangered species by the USFWS on August 25, 1999, and is no longer subject to the Endangered Species Act. There is also designated critical habitat for marbled murrelet and spotted owl on Forest Service land in the upper watershed.

Bull trout, which has since been listed as a threatened species, is addressed under Fishery Resources (Section 3.5). Oregon spotted frog and mardon skipper are the two candidate species.

<u>3.7.2.1 Bald Eagle</u>

Habitat Requirements and Population Status

The bald eagle is federally listed as threatened in Washington. This species is found only in North America and ranges over much of the continent, from the northern reaches of Alaska and Canada to northern Mexico. Bald eagles migrate to wintering ranges in Washington in late October and are most commonly found along lakes, rivers, marshes, or other wetland areas west of the Cascade Range, with an occasional occurrence in eastern Washington. Individual wintering eagles have been shown to fly long distances between feeding areas in different basins throughout the West Coast, presumably following food abundance (Hunt et al. 1992).

The limiting features of bald eagle breeding habitat are nest sites, perch trees, and available prey. Bald eagles primarily nest in unevenly aged, multi-storied stands with old-growth components (Anthony et al. 1982). Factors such as tree height, diameter, tree species, position on the surrounding topography, distance from water, and distance from disturbance also influence nest selection. Live, mature trees with deformed tops are often selected for nesting, and nests are often reused year after year. Snags, trees with exposed lateral branches, or trees with dead tops are often present in nesting territories and are critical to eagle perching, movement to and from the nest, and as points of defense of their territory. Perches used for foraging are normally close to water where fish, waterfowl, seabirds, and other prey can be captured.

In addition to foraging and perching habitats required during breeding, wintering eagles use communal night roosts that are usually in old-growth coniferous forest within 1 to 2 miles of foraging habitats. These communal roosts help ameliorate weather extremes and likely serve social functions (Stalmaster 1987).

Known Occurrences in the Green/Duwamish River Basin

Bald eagles have been sighted every month of the year near the Howard Hanson Reservoir and near Eagle Lake. The bald eagle is primarily a winter resident in the basin, mainly between October 31 and March 31, and has been observed foraging at the reservoir and along the Green River and Tacoma and Pioneer Creeks (USFS 1996). Although its behavior in the area is not documented, it most likely feeds on waterfowl that winter on the reservoir. Up to 200 ducks may be on the reservoir at any one time, providing a readily available food source for bald eagles. The forests surrounding the reservoir provide a large number of perches and potential nest trees, but no nest trees or night roosts have been identified. Food is the limiting resource and no more than four bald eagles have been seen in the vicinity of the reservoir at any one time during the winter.

3.7.2.2 Northern Spotted Owl

Habitat Requirements and Population Status

The northern spotted owl was federally listed as threatened throughout its range on July 23, 1990. Some of the National Forest land within the basin is designated Critical Habitat for the northern spotted owl and is part of the 120,000-acre Critical Habitat Unit (CHU) #WA-34. Spotted owls can be found throughout the west slope of the Cascade Range below elevations of 4,200 feet. Preferred habitat is composed of large contiguous blocks of mature or old-growth coniferous forests with multi-layered, multi-species canopies. Habitat characteristics include moderate to high (60 to 80 percent) canopy closure, large overstory trees, substantial amounts of standing snags, in-stand decadence, and coarse woody debris of various sizes and decay classes scattered on the forest floor (Gore et al. 1987).

Spotted owls do not build their own nests but rely on naturally occurring nest sites, such as broken trees tops and cavities. In western Washington, spotted owls nest most often in cavities of trees with a diameter at breast height (dbh) greater than 20 inches. In fact, there is a fair amount of evidence that spotted owls require old-growth forests for reproduction. One study found that 1,282 out of 1,502 owl observations were in old-growth, 22 were in mature forest, 131 were in old-growth/mature forest, and 67 were in stands less than 100 years of age, demonstrating an overwhelming preference for old-growth. (Corps 1997a)

Known Occurrences in the Green/Duwamish River Basin

Suitable spotted owl habitat within the upper basin is limited due to past logging activities. There are, however, 35 known spotted owl activity centers, 14 of which are pairs that are known to have produced at least one young (USFS 1996). There are three additional activity centers located outside the basin that have a portion of their 1.8-mile provincial home range radius located within the basin. All activity centers occur on National Forest land (USFS 1996). Due to a lack of suitable habitat features in the remainder of the basin, it is unlikely that spotted owls occur in other parts of the basin.

In 1989 and 1990, a single spotted owl was detected in the Charley Creek drainage, approximately 1 mile from the Howard Hanson Reservoir. This detection prompted the Washington Department of Natural Resources (DNR) to conduct a formal spotted owl survey from 1992 to 1994. The survey did not find any further spotted owl activity within the drainage. (Corps 1997a)

3.7.2.3 Marbled Murrelet

Habitat Requirements and Population Status

The marbled murrelet was officially listed as a threatened species on October 1, 1992. Areas within Wolf, Champion, and Rock Creek drainages, and an area around Twin Camps, all in the upper basin, are designated Critical Habitat for marbled murrelets (CHU #WA-11a; USFS 1996). Murrelets live near shallow marine waters and, in Washington, nest in mature and old-growth trees. Murrelets do not construct nests but use existing platforms in larger trees. Platforms generally consist of large lateral branches (greater than 4 inches diameter) that are usually moss or lichen covered, but may also consist of wide areas where lateral branches fork or there are deformities such as dwarf-mistletoe (USFWS 1997). Nest stand characteristics generally include a second story of the forest canopy that reaches or exceeds the height of the nest limb, thereby providing a protective enclosure surrounding the nest site. A single, large, closed-crowned tree, which provides its own protective cover over the nest site, may also be used by murrelets. Marbled murrelet nests have been located in stands as small as 7 acres and are generally within 50 miles of marine waters (Hamer and Nelson 1995). Murrelet detections have been found to increase in areas where old-growth and mature habitat make up over 30 percent of the landscape and decline when clearcut and open meadow habitat occur over 25 percent of the landscape (Hamer and Cummins 1990).

Known Occurrences in the Green/Duwamish River Basin

Available information suggests that the habitats within the upper basin could support nesting pairs. Reasons for this determination include the fact that the area is approximately 30 to 40 miles from Puget Sound and, though uncommon, a few stands of large trees exist at lower elevations (e.g., Twin Camps and Sawmill Ridge; USFS 1996). A limiting factor may be the fragmentation of coniferous forests and overall low percentage of old-growth and mature forest in the basin.

Detections of marbled murrelets were made on 1,100 acres of USFS land during 1999 protocol surveys in the upper Green River basin. This is the first substantiated record of marbled murrelet nesting in the Green River basin. Occupancy has only been detected on USFS land that is more than 7 miles east of the HHD reservoir (Stebbins 2000). A query of the Washington Department of Fish and Wildlife (WDFW) Priority Habitats and Species (PHS) database in December 1995 had revealed no record of marbled murrelet use in upper basin. During 1994, marbled murrelet surveys were conducted near the Howard Hanson Reservoir within three stands identified by WDFW and Corps biologists as marginally suitable for murrelet nesting. No marbled murrelets were detected during the surveys. No other stands near the reservoir contain trees with suitable nest characteristics. Marbled murrelet surveys were also conducted in a 5- to 10-acre stand located north of the Tacoma Diversion Dam in 1994 and 1995 following the protocol developed by the Pacific Seabird Group (Ralph et al. 1994). No marbled murrelet activity was detected during either survey year (Beak 1994, 1995). Timberland owners and the USFS have also conducted numerous murrelet surveys over the past three years in the upper basin and the Huckleberry Ridge area. No detections have been recorded during these surveys.

3.7.2.4 Gray Wolf

Habitat Requirements and Population Status

The gray wolf is listed as an endangered species in Washington and can use a broad spectrum of habitats provided that there is an abundance of prey (generally ungulates) and that suitable denning and rendezvous sites exist away from human disturbance. The availability of prey may be the primary factor in determining habitat suitability (Stevens and Lofts 1988). Den sites are most commonly burrows in sandy soils, but can be located in a variety of settings from downed logs and hollow trees to rock caves. Rendezvous sites tend to be near a source of open water in small meadows with limited visibility.

Known Occurrences in the Green/Duwamish River Basin

Surveys were conducted for gray wolves on Huckleberry Ridge between the upper Green River and White River Watersheds in 1993. During those surveys, no wolves were heard and evidence of wolf use of the area was not observed. There has been one class 2 (reliable but unconfirmed) gray wolf sighting within the upper basin, and several to the north, south, and east (USFS 1996). USFS biologists suspect there is a rendezvous site near Mt. Rainier, but that the upper basin is used only as transitory habitat due to high road density and lack of secure habitat (USFS 1996). The abundance of elk in the upper basin, however, provides suitable prey. Gray wolf use of the middle and lower basins is also unlikely for the same reasons as the upper basin, as well as the higher degree of residential, agricultural, and industrial development.

3.7.2.5 Grizzly Bear

Habitat Requirements and Population Status

The grizzly bear is a federally listed threatened species. The North Cascades Grizzly Bear Recovery Zone has been designated north of Interstate 90, to the north and east of the Green/Duwamish Basin. The grizzly bear is not closely associated with late-successional forests, but inhabits vast areas of diverse habitat types including alpine meadows. The presence of an abundance of berries, vegetation, fish, and other food is necessary to support these large omnivores. Grizzly bears have large home ranges of up to 1,004 square miles. They usually move to lower elevations after emerging from their high elevation denning areas in the spring. Most often, grizzly bears are found in remote areas where human activity is limited and roads are few or closed to access, especially to hunting. (Corps 1997a)

Known Occurrences in the Green/Duwamish River Basin

No grizzly bears or sign of grizzly bears have been reported in the basin. However, in 1993, the WDFW verified tracks of a grizzly adult, cub, and an unknown aged bear near Kapowsin in Pierce County. There have also been several reliable sightings on the Cle Elum Ranger District, just east of the upper basin, as well as others to the north and south (USFS 1996). Habitat conditions in the Green/Duwamish Basin are not highly suitable for grizzly bears for the same reasons given for gray wolf: high road density and little security habitat. However, the abundance of elk as a prey base and the variety of plant foods would provide usable habitat.

3.7.2.6 Canada Lynx

Habitat Requirements and Population Status

The Canada lynx was officially listed as threatened April 24, 2000 under the Endangered Species Act and is listed as threatened by the WDFW. In the western half of the contiguous United States, lynx are known from Washington, Oregon, Idaho, Montana, Utah, Wyoming, and Colorado. In Washington, resident lynx populations historically occurred in the northeastern and north-central portions of the state along the eastern slope of the Cascade Mountains south at least to Mt. Rainier National Park (USDI Bureau of Land Management, National Park Service, Fish and Wildlife Service, USDA Forest Service 1999).

Declines in lynx populations have been attributed to significant alterations in habitat caused by timber harvest and trapping (Washington Department of Wildlife 1993, 63 FR 36994-37013, July 8, 1998). Although significant natural population cycles in the lynx are well documented, available evidence indicates that populations in northeastern Washington have been depressed for at least the last 20 years, with no indication of population increases typical of lynx populations during more favorable years (Washington Department of Wildlife 1993).

The distribution of lynx throughout its range and that of its primary prey, the snowshoe hare (*Lepus americanus*), is closely tied to the distribution of boreal forest. In north-central Washington, these habitats consist primarily of Engelman spruce, subalpine fir, lodgepole pine, and aspen forests. In northeastern Washington, lodgepole pine retains its importance within lynx home ranges, but western red cedar and western hemlock are also used. Lynx require two structurally different forest types: early successional forest types for foraging and late successional forests that contain cover for kittens and denning. Intermediate stages may be used as travel corridors that provide connectivity between foraging and denning and cover habitats (Koehler and Aubrey 1994).

In Washington, lynx use dominant stands greater than 150 years of age with LWD such as fallen trees or upturned stumps for denning. Dens are typically situated on northeast aspects in stands of Engelmann spruce, subalpine fir, and lodgepole pine. A high density of fallen logs greater than one foot in diameter appear to be required. Minimal human disturbance, proximity to travel corridors, nearby foraging habitat, and a stand size of at least 5 acres appear to be additional components of lynx denning habitat (Washington Department of Wildlife 1993, Koehler and Aubrey 1994).

Known Occurrences in the Green/Duwamish River Basin

There are no reported sightings of lynx in the Green River Basin. The USFS has been conducting studies of potential lynx habitat on the Mt. Baker-Snoqualmie National Forest. The USFS has defined suitable habitat as areas of permanent winter snowpack, within Pacific silver fir, mountain hemlock, and subalpine fir zones, and areas supporting snowshoe hare, the principal prey of lynx (Olnedo pers. comm.).

Permanent winter snowpack in the Green River Basin occurs at approximately 2,800 feet in elevation on the western slope of the Cascades. Any potential lynx habitat would therefore be located in the upper Green River Basin above HHD on USFS land, well above the location of proposed fish habitat restorations.

<u>3.7.2.7 Spotted Frog</u>

Habitat Requirements and Population Status

The spotted frog is listed as a candidate species in Washington. Spotted frog populations have declined dramatically in both western Washington and Oregon. In Washington, the species is known to occur at several locations east of the Cascade Range, but is now gone from many former breeding locations in the Puget Sound lowlands (Leonard et al. 1993). It is believed that the non-native bullfrog and other aquatic predators have seriously reduced these populations. Adult spotted frogs are found in or near perennial water bodies such as springs, ponds, lakes, or slow moving streams and are often associated with emergent, non-woody vegetation (Leonard et al. 1993). It is rare to find a spotted frog more than 3 feet away from water. They tend to sit in the shallows, half submerged, or they float in deeper water, clinging to aquatic vegetation with their head visible. Spotted frogs eat invertebrates and adults can eat other small frogs (Light 1986).

Known Occurrences in the Green/Duwamish River Basin

The basin lies within the historic range of the spotted frog. Sightings in Thurston County are the only confirmed observations of spotted frogs in 23 years in western Washington lowlands. Within the Green/Duwamish Basin, perennial water sources with adjacent emergent vegetation could provide suitable spotted frog habitat. Nevertheless, due to the rare documented occurrence of the spotted frog in western Washington lowlands, it is not expected to occur in the middle or lower basin at this time. One unconfirmed individual was reported during USFS surveys of Upper Sunday Creek in the upper basin (USFS 1996), but because the identification was unconfirmed and there are no other reports, the spotted frog is still believed to be unlikely to occur there as well.

3.7.2.8 Mardon Skipper

Habitat Requirements and Population Status

The mardon skipper is listed as a candidate species in Washington. In the Puget lowlands, the mardon skipper is found on glacial outwash prairies where it inhabits open grasslands with abundant Idaho fescue interspersed with early blue violet (Potter et al. 1999). Much of the native grasslands and savannas that the mardon skipper typically inhabits are fragmented, degraded, and developed leaving little habitat for the butterflies. A few hundred individuals have been identified within nine geographically isolated sites within Washington of which three are in the Puget Sound region. No estimates were made prior to 1980, but the species is believed to have declined severely due to loss of habitat (Potter et al. 1999).

Known Occurrences in the Green/Duwamish River Basin

The basin lies within the historic range of the mardon skipper. Within the Green/Duwamish Basin, grasslands could provide suitable mardon skipper habitat. Nevertheless, due to the rare documented occurrence of the mardon skipper in western Washington lowlands, it is not expected to occur in the middle or lower basin at this time. At this time, there have been no confirmed sightings of mardon skippers in the Green/Duwamish Basin (Potter et al. 1999).

3.8 Air Quality

3.8.1 Regulatory Overview

3.8.1.1 National Ambient Air Quality Standards

In accordance with the Clean Air Act and its amendments, National Ambient Air Quality Standards (NAAQS) have been established by the Environmental Protection Agency (EPA) for several criteria pollutants including lead (Pb), ozone (O3), carbon monoxide (CO), sulfur dioxide (SO2), nitrogen dioxide (NO2), total suspended particulates (TSP), and particulates with aerodynamic diameters of less than 10 microns (PM10 and PM2.5).

Air quality standards are shown in Table 3-7. Some pollutants are subject to both "primary" and "secondary" standards. Primary standards are designed to protect human health with a margin of safety. Secondary standards are established to protect the public welfare from any known or anticipated adverse effects associated with these pollutants such as soiling, corrosion, or damage to vegetation.

3.8.1.2 Prevention of Significant Deterioration

Prevention of Significant Deterioration (PSD) regulations were established by the EPA to ensure that new or expanded sources of air pollution do not cause a significant deterioration in air quality in areas that currently meet ambient standards. EPA has developed a list of 28 major source categories by which types of facilities are classified for PSD regulations. The threshold for determining whether a facility is a major source, and therefore subject to PSD regulations, is whether a facility that falls within one of the 28 listed categories emits more than 100 tons per year of any criteria pollutant or whether a facility not listed emits more than 250 tons per year of a criteria pollutant. The PSD regulations also set ambient impact increments that limit the allowable increase of ambient concentrations of criteria pollutants.

The most stringent increments apply to "Class I" PSD areas, which include wilderness areas and national parks. The intent of the PSD increments is to prevent air quality in areas with concentrations below the ambient air quality standards from reaching the standards (i.e., keep pristine and clean areas clean). The Class I areas closest to the project area are the Alpine Lakes Wilderness Area and Mt. Rainier National Park.

3.8.1.3 Compliance with NAAQSs and Other Air Quality Standards

Three agencies have jurisdiction over air quality in the project area: the EPA, Ecology, and the Puget Sound Clean Air Agency. These agencies establish regulations that govern both the concentrations of pollutants in the outdoor air and contaminant emissions from air pollution sources. Although their regulations are similar in stringency, each agency has established its own standards. Unless the state or local jurisdiction has adopted more stringent standards, the EPA standards apply.

Table 3-7. National and State of Washington Ambient Air Quality Standards

	National (EPA)		
Pollutant	Primary	Secondary	Washington State
Particulate Matter			
PM_{10}			
Annual average	50 Φg/m^3	50 Φg/m^3	50 Φg/m^3
24-hour average	150 Φg/m^3	150 Φg/m^3	150 Φg/m^3
$PM_{2.5}$			
Annual average	15 Φg/m^3	15 Φg/m^3	15 Φg/m^3
24-hour average	65 Φg/m^3	65 Φg/m^3	65 Φg/m^3
Lead			
Quarterly average	1.5 Φg/m^3	1.5 Φg/m^3	1.5 Φg/m^3
Sulfur Dioxide			
Annual average	0.03 ppm	No standard	0.02 ppm
24-hour average	0.14 ppm	No standard	0.10 ppm
3-hour average	No standard	0.50 ppm	No standard
1-hour average	No standard	No standard	0.40 ppm[a]
Carbon Monoxide			
8-hour average	9 ppm	9 ppm	9 ppm
1-hour average	35 ppm	35 ppm	35 ppm
Ozone			
8-hour average[b]	0.08 ppm	0.08 ppm	0.08 ppm
Nitrogen Dioxide			
Annual average	0.05 ppm	0.05 ppm	0.05 ppm

Notes: Annual standards never to be exceeded. Short-term standards not to be exceeded more than once per year unless noted.

ppm = parts per million
PM_{10} = particles 10 microns or less in size
$PM_{2.5}$ = particles 2.5 microns or less in size
Φg/m^3 = micrograms per cubic meter

[a] 0.25 ppm not to be exceeded more than two times in 7 consecutive days.
[b] Not to be exceeded on more than 1 day per calendar year as determined under the conditions indicated in Chapter 173-475 WAC.

Source: Washington Department of Ecology 1998a.

Ecology and the Puget Sound Clean Air Agency maintain a network of air quality monitoring stations throughout the Puget Sound area. In general, these stations are located where there may be air quality problems, and so they are usually in or near urban areas or close to specific large air pollution sources. Other stations are located in remote areas to provide an indication of regional air pollution levels. Based on monitoring information collected over a period of years, the state and federal agencies designate regions as being “attainment” or “nonattainment” areas for particular pollutants. Attainment status is a measure of whether air quality in an area complies with the federal health-based ambient air quality standards shown in Table 3-7.

The project area is classified as an attainment area for all criteria pollutants except CO, ozone, and PM 10. For CO and ozone, the region is classified as a maintenance area, which is a provisional attainment status that must be maintained for several years before being reclassified as full attainment. There are three pockets of PM10 nonattainment areas in the region, including industrial areas in Seattle, Kent, and the Tacoma Tideflats (Ecology 1999).

3.8.2 Existing Air Quality

Air quality conditions in the basin are quite variable and are influenced by several factors including climate, topography, and the nature of pollution sources (e.g., residential or industrial sources). Air quality throughout the basin is generally good, though there are certain times of the year when some pollutants can cause air quality problems.

In general, periods of drought and high temperatures peak toward the end of July and August and are coupled with light, variable winds. Late summer is also when localized problems with fugitive dust and particulates from logging trucks driving on unpaved surfaces and burning of timber slash can occur (burning is prohibited during times of high forest fire potential).

In the Green River Valley, temperature inversions can occur as a result of low solar heating during the winter months. During these stable atmospheric conditions, high concentrations of pollutants associated with wood burning (stoves) and transportation sources can occur. This condition is intensified in the valley because of the additional confinement of air flow by the valley walls. (Corps 1997b)

In the lower basin, the high concentration of industrial sources and automobiles has caused air quality problems. Motor vehicles are the largest source of air pollutants in King County. As in other parts of the basin, most problems occur during the dry portion of late summer when weather patterns are stable and there are only slight onshore or offshore winds, or during mid-winter stable periods of thermal inversions. (Corps 1997b)

3.9 Noise

3.9.1 Background Information

State, county, and local noise regulations specify standards that restrict both the level and duration of noise measured at any given point within a receiving property. The maximum permissible environmental noise levels depend on the land use of the property that contains the noise source (e.g., industrial, commercial, or residential) and the land use of the property receiving that noise.

The Green/Duwamish River Basin includes approximately 483 square miles in King County; therefore the King County noise standards would be applicable to restoration projects conducted in the basin. The King County noise standards are shown in Table 3-8.

Table 3-8. King County Environmental Noise Limits (dBA)

	District of Receiving Property			
District of Noise Source	Rural Day/Night	Residential Day/Night	Commercial	Industrial
Rural	49/39	52/42	55	57
Residential	52/42	55/45	57	60
Commercial	55/45	57/47	60	65
Industrial	57/47	60/50	65	70

Source: King County Code Chapter 12.88.

3.9.2 Affected Environment

Existing sound levels throughout the basin are highly variable depending on location. Sound levels range from relatively loud noises associated with urban and industrial activities on the Duwamish River in the lower basin to very quiet rural environments in the upper basin. Noise sources include traffic on roads, aircraft overflights, and natural sounds such as wind through trees and water falling over rocks. It is highly unlikely that noise standards in the upper basin would be exceeded under existing conditions. In portions of the lower basin, especially near industrial areas, sound levels could occasionally exceed noise standards under certain conditions.

3.10 Traffic and Transportation

The roadway network within the Green River Basin ranges from logging roads in the upper basin to interstate freeways in the lower basin near Seattle. Traffic volumes on individual roads reflect their usage, ranging from infrequently traveled logging roads in the upper basin to Interstate 5 with thousands of vehicles per day. Roadway composition varies from gravel logging roads to well-developed freeways and arterials.

Going from east to west, major roadways in the Green/Duwamish River Basin include the Veazie-Cumberland Road, State Route 169, the Green Valley Road, the Auburn-Black Diamond Road, State Route 18, State Route 516, State Route 167, the Kent-Des Moines Road, State Route 181, State Route 169, and Interstate 5. In addition, there are numerous arterials and city streets throughout the Green/Duwamish River Basin. Speed limits range from 25 miles per hour on local streets to 60 miles per hour on freeways.

3.11 Land and Shoreline Use

3.11.1 Land Use

3.11.1.1 Historic Land Use

The last 150 years of Euro-American settlement and development in the Green/Duwamish River Basin have fundamentally shaped the conditions found today within the basin. The Green/Duwamish Basin was among the first areas of the Puget Sound region to be extensively settled by Euro-American immigrants. Though the early Euro-American settlers encountered a vigorous native culture that had lived in the Green/Duwamish Basin and along the shores of the estuary for centuries, the new inhabitants immediately began altering the landscape to fit their particular needs. The results of those alterations, many of which continue today, loom large in the present life of the river. Table 3-9 identifies some specific events and results of changes to the river and riparian zone in the latter half of the 19th century and into the 20th century. The initial Euro-American settlement and subsequent development of the Green/Duwamish Basin was integrally related to agriculture, railroad, logging, mining, and Corps activities (Corps 1997b).

Since the 1940s, the valley from Auburn to Tukwila has experienced a dramatic increase in urbanization. Formerly prime farmlands have been converted to warehouses, malls, and parking areas due to their proximity to Interstate 5 and the flat, easily developable land. Most of this development has occurred without benefit of planning or growth management. Additionally, the lower hills, especially in the area of Big Soos Creek and Covington Creek, have experienced rapid suburban residential development (Corps 1997a).

3.11.1.2 Current Land Use

Upper Basin

The upper basin consists entirely of unincorporated land where the major land use is logging. No permanent settlements currently exist in this part of the basin, though the small towns of Lester, Nagrom, and Maywood once supported small populations as logging, mining, and railroad stops. Burlington Northern Railroad is in the process of reopening its rail line from Auburn through the upper basin and over Stampede Pass to Yakima. (Corps 1997b)

Public access is restricted in the upper basin due to its use as a municipal watershed by the City of Tacoma. Howard Hanson Dam (HHD) and Tacoma Diversion Dam continue to operate in the upper basin to provide downstream flood protection and municipal water supply.

The upper basin has multiple ownership including the Mt. Baker-Snoqualmie National Forest, Plum Creek, Weyerhaeuser, Washington Department of Natural Resources (DNR), and the City of Tacoma.

Table 3-9. Chronology of Events in the Green/Duwamish River Basin 1850 to 1963

Date	Event	Result
1850	Oregon Donation Land Act	Land granted to settlers after 5 years homesteading
1851	First Euro-American settlers arrive in the Duwamish area	Land clearing begins – three claims filed
1852	Livestock introduced into the Green River Valley	Grazing begins on land
1853	Extension of Land Act through 1855	Seventeen claims filed along the river
1854	First road built in King County	Road built through the river valley
1855-58	Removal of debris from river for navigational purposes	Aid navigation within Green River
1855-56	Indian Wars	Settlers move to Seattle for protection – settlement slows
1856	Land clearing resumes	Duwamish area gardens planted, orchards established, timber cutting begins
1858	Drainage Laws	County passes laws permitting ditches for drainage, swamp land drainage begins
1862	Homestead Act	Settlement of territory encouraged
1866	Population of valley starts to grow in earnest	
1867	First railroad bridge built across Black River	Local railroad construction begins in Green/Duwamish River Basin
1870	277 settlers living in valley	
1870s	Major railroads build lines	Pace of logging increases in Green/Duwamish River Basin
1875	Channel Improvement Act	County road funds used for improvement of rivers
1880-1910	Extensive logging occurs in the basin	
1883	Railroad bridge built across White River	Northern Pacific Railroad constructs east-west line through Green River Valley
1893	Great Northern Railroad develops lines in north to south direction in the valley	
1895	Drainage District Act	County Drainage Districts formed
1895	Duwamish East Waterway construction begins	East Duwamish Waterway dredged and used for Harbor Island fill
1902	Green River Hatchery built	State operated Green River Hatchery opens on Soos Creek
1901-04	Hydraulic sluicing of Beacon Hill	Fill placed in the intertidal area of the Duwamish River to raise land and decrease flooding potential
1906	Major flooding in rivers during fall and winter	Log jam on lower White River forces flood water into the Puyallup River
1902-27	Interurban Electric railway	Interurban rail eclipses riverboat travel
1910	Tacoma Water Diversion authorized	Construction of the Tacoma Diversion Dam on the Green River is begun for municipal water

Date	Event	Result
1911	White River Diversion	White River completely diverted to Puyallup River to reduce flooding problems
1913	Tacoma Water Diversion completed	Water diverted from Green River
1916	Black and Cedar Rivers diverted from Green/Duwamish River	Ship Canal cut to Lake Union draining Lake Washington to Puget Sound – reduced flooding in Green/Duwamish Basin
1917	East-West Duwamish Waterways finished	Dredging of channel completed – 2.2 sq. miles of Duwamish intertidal area filled; potential of flooding is reduced
1919	Private and County levees built to protect lowlands from flooding	Encouraged more productive agricultural use
1959	One of the largest floods on record (28,000 cfs at Auburn)	Significant property damage
1960s	Extensive levee building by local and federal government	Channelization of the river
1963	Howard A. Hanson Dam completed	Reduces maximum flow of Green River to 12,500 cfs at Auburn to reduce flooding

Note: cfs = cubic feet per second

Source: Corps 1997b

Middle Basin

Much of the middle basin is unincorporated lands, though the basin does include all or portions of the incorporated cities of Algona, Auburn, Black Diamond, Covington, Des Moines, Enumclaw, Federal Way, Kent, Maple Valley, Normandy Park, Renton, SeaTac, and Tukwila. The incorporated areas are concentrated in the lower portion of the middle basin. Although residential development is rapidly increasing throughout the entire basin, agriculture and park land remain the dominant land uses within the upper portion of the middle basin. In the lower portion of the middle basin, industrial, residential, and commercial land uses are dominant near the river.

Lower Basin

The larger population centers and industrial, commercial, and residential land uses are concentrated in the lower basin. Almost the entire lower basin is included in the incorporated cities of Burien, SeaTac, Seattle, and Tukwila. Though some park lands and residential land uses occur next to the Duwamish River, the majority is developed for commercial and industrial use.

3.11.1.3 Relevant Land Use Plans

The Green/Duwamish Basin includes lands managed by federal, state, and local agencies in addition to private owners. Relevant federal and state plans, guidelines, projects, or legislation include:

- Mt. Baker-Snoqualmie National Forest Land and Resource Management Plan (USFS)

- National Environmental Policy Act
- Washington State Environmental Policy Act
- State of Washington Growth Management Act
- State of Washington Shoreline Management Act

The comprehensive plan, zoning ordinance, Shoreline Management Master Program, and subarea plans, as well as the relevant policies and land use designations from these documents, of the following jurisdictions also apply:

- King County
- Cities of Algona, Auburn, Black Diamond, Burien, Covington, Des Moines, Enumclaw, Federal Way, Kent, Maple Valley, Normandy Park, Renton, SeaTac, Seattle, and Tukwila

3.11.2 Shoreline Use

3.11.2.1 Historic Shoreline Use

In 1854, the Green/Duwamish River system included 1,900 linear miles of river and streams. By 1985, 125 linear miles of the river system remained. If the portions of the system that have been disconnected are included in the calculations, the value rises to 380 miles and includes 193 miles in the Cedar/Lake Washington Watershed and 62 miles in the White River Watershed. This is still a 66 percent reduction in accessible river (Corps 1997b).

In 1913, the City of Tacoma completed a water diversion dam on the Green River near the town of Palmer. Tacoma Diversion Dam reduced the flow in the lower and middle reaches of the Green/Duwamish River. In 1963, Howard Hanson Dam was built by the Corps in the Eagle Gorge. Located upstream of the Tacoma Diversion Dam, the main purpose of this dam was flood control, with both water supply and fisheries conservation as further authorized purposes. (Corps 1997b)

Prior to 1970, numerous levees and revetments were constructed along the Green River to protect property from flooding and erosion. After 1970, levees were not built because of the recognized adverse effects of these projects on fish habitat.

3.11.2.2 Current Shoreline Use

Upper Basin

Other than the modification of the shoreline by HHD and Tacoma Diversion Dam, no major shoreline developments exist in the upper Green/Duwamish Basin.

Middle Basin

The existing channel of the Green River is considerably more uniform than the predevelopment channel. Fewer river miles, less shoreline, and considerably less estuary characterize the channel downstream from Flaming Geyser Park. Other than an area of multiple channels near Metzler/O'Grady Park (RM 40.6 to RM 36.9), much of the river is confined by levees or has assumed a single-thread configuration since completion of HHD. Significant decreases in channel length, channel and estuary shoreline, and channel width can be seen from measurements made from the aerial photographs and from maps supplied by U.S. Geological Survey (USGS), the Corps, and other sources. Decreases in channel length were mainly the result of levee projects that cut off multiple side channels and sloughs in the reach from Flaming Geyser Park downstream through the City of Auburn. In this reach from RM 43 to RM 33, there are 20,045 feet of bank armoring and protection, or 18 percent of the shoreline. Approximately 46 percent of the total bank protection measures are found in the area from RM 36.9 to RM 33, or the approximate lower end of the existing braided area. Overall, the river appears to have been shortened by some 10.4 miles in the reaches from the estuary to the lower end of the Green River Gorge at RM 47 (Corps 1997b).

Most of the levees and revetments were built in three time periods. The upper two levees, in Flaming Geyser State Park, were built in 1950 and 1959. The central group of levees between Flaming Geyser State Park and Metzler/O'Grady Park were built in 1936. One of these levees was extended in 1974. Downstream of Metzler/O'Grady Park, a set of levees from SR 18 to about RM 38.3 were built from 1960 to 1964. The Ross revetment at RM 36.6 was built in 1988 (Perkins 1993). Furthermore, a calculation from Perkins' estimate suggests that about 80 percent of the river between RM 33 and the City of Kent (RM 17) has either a levee or revetment on at least one bank (this is a minimum of 16 miles of bank protection). From Kent downstream, virtually the entire river (about 95 percent of the 17 miles) is leveed or revetted on both banks (Corps 1997b).

Lower Basin

In the lower basin, the loss of shoreline is quite dramatic. The Duwamish River and estuary have been extensively dredged, channelized, and straightened. The Duwamish Estuary is estimated to have had a shoreline of 93,000 feet and 3,850 acres of tidal mudflat, marsh, and swamp. By 1986, only 25 acres of mudflat and 20 acres of tidal marsh remained. No tidal swamps existed. The channel had been further reduced to only 19,000 feet of riparian shoreline, with 53,000 feet of developed shoreline. Approximately 21,000 feet had been lost in the straightening of the channel (Blomberg et al. 1988).

Because of the degradation of fish habitat (see Section 3.5 – Fishery Resources), King County Surface Water Management has recommended a policy of preventing future development in channel migration hazard areas through land use regulation. The King County Council formally adopted this policy as part of the King County Flood Hazard Reduction Plan in November 1993 (Corps 1997b).

3.12 Recreation

The Green/Duwamish River Basin is a heavily used recreation area both for water sports and more passive activities, such as fishing, bird watching, and hiking. Federal, state, King County, and local municipalities are involved in improving a system of parks within the Green/Duwamish Basin. Existing facilities include numerous municipal parks, golf courses, picnic facilities, and the Interurban Trail along the levees of the Green River.

3.12.1 Upper Basin

Generally, recreation is not allowed in the upper basin above Tacoma Diversion Dam. However, some fishing and recreational hunting is allowed annually. Additionally, a network of trails covers the Mt. Baker-Snoqualmie National Forest portion of the upper basin.

3.12.2 Middle Basin

The existing recreational facilities in the Green/Duwamish Basin include numerous municipal parks, golf courses, picnic facilities, and the Interurban Trail along the levees of the Green River. Most of these facilities are located within the middle basin. Considerable water recreation occurs in the river above the City of Tukwila.

The primary recreation area in the Green/Duwamish Basin is the Green River Gorge region. Access to the river in the vicinity of the Gorge allows for recreational activities, such as fishing, floating, canoeing, kayaking, white-water rafting, and hiking. Sport fishing for a variety of trout and salmon species is also a traditional pastime.

The two major state parks located in the Green River Gorge region are Flaming Geyser State Park and Kanaskat-Palmer State Park. Flaming Geyser is a day-use only park with an average annual attendance of approximately 575,000 visitors. Activities include picnicking, swimming, river rafting and inner tubing, and hiking. Kanaskat-Palmer State Park is open for day-use and overnight camping. One of the primary uses of the park is as a put-in or take-out site for river rafters and kayakers. Average annual attendance is 250,000 visitors (Corps 1997b).

Washington State Parks and Recreation Commission owns several other sites in the Green River that are undeveloped. These sites include the Kummer Bridge Area, Black Diamond Heritage Area, Hanging Gardens Recreation Area, and Walter A. Jellum Area (WSPRC 1991 and 1995). Several groups actively use the Green River for boating including the Washington Kayak Club, Western Canoeing, Inc., Paddle Trails Canoe Club, Northwest Rivers Council, Washington Water Trails, Friends of the Green River, Washington Recreational River Runners, and River Recreation, Inc.

King County also operates several parks in the middle basin including Metzler Park, O'Grady Park, Whitney Bridge County Park, East Green River County Park, Auburn Regional Park, and North Green River County Park. Primary activities at these parks are fishing, walking, and picnicking. Attendance records are not available, but use is moderately heavy. The King County parks are maintained primarily as natural areas, with special emphasis on fishing opportunities. Ft. Dent Park, located at the confluence of the Black River and the Green River, has playfields and other improvements for day-users. Individuals and groups (e.g., Alpine Fly Fishers, Trout Unlimited, and the Renton Fish and Game Club) use these parks, as well as other areas of the Green/Duwamish Basin for fishing.

Other popular forms of recreation along the Green River are walking and bicycling along the Green River Trail and the Interurban Trail; major portions of these trails lie within the middle basin. These trails are generally located on top of levees beside the river and provide good views of the river. The trails provide ample opportunity for long-distance cycling and walking. Many organized recreation groups use roads and trails in the Green/Duwamish Basin, such as equestrian groups, bicycle clubs, and hiking groups.

Many of the tributaries to the Green River and nearby communities have parks along or near the water including Big Soos Creek Park, Lake Meridian Park, Mill Creek Canyon Park, Isaac Evans Park, Kent Riverfront Park, and Earlington Park. These facilities are primarily used by local residents for fishing and walking.

There is intense public interest in use of HHD to enhance white-water recreational opportunities (Corps 2000). In recent years the Corps has placed less emphasis on these needs while still considering them in management decisions (Corps 1998).

3.12.3 Lower Basin

Recreation in the lower basin is limited due to the intensive urban and industrial development along the river. Trails do exist along portions of the Duwamish River, and local parks occur in the vicinity of the river (e.g., Duwamish River Park, Foster Golf Course, the Allentown Pea Patch, and portions of the Green River Trail).

3.13 Visual Quality and Aesthetic Resources

At a regional level, landscape settings are determined by topography, which establishes overall visual character at a broad scale. Human development modifies the landscape settings, and thus the visual character. The type and degree of the development help to determine the extent of the modification; therefore, the visual quality and aesthetics of a region are determined by its topography and land use.

The Green/Duwamish River originates in the Mount Baker-Snoqualmie National Forest in the high Cascade Mountains of southeastern King County and flows southwest 90.5 miles to the Puget Sound at Elliott Bay. The entire Green/Duwamish River Basin encompasses mountain, foothill, and lowland topography. Human development within the Green/Duwamish Basin is as diverse as its topography. The river has experienced varied development over the last 150 years, which has dramatically altered the environment. The extent of development increases as one proceeds downriver from the relatively undeveloped headwaters of the river to the highly urban/industrial areas of the Duwamish delta. Typically, areas with more dynamic topography have less human development, and thus have a greater visual quality.

3.13.1 Upper Basin

The upper basin of the Green/Duwamish River extends from its headwaters high within the Cascade Mountains to Howard Hanson Dam (HHD). This is an area of complex topography. The dominant land use in the upper basin continues to be logging. No major permanent settlement exists in the basin and public access is restricted due to the municipal watershed for the City of Tacoma.

The combination of mountainous terrain covered by coniferous forests and limited land use establishes this area as one of the most scenic in the entire Green/Duwamish Basin. Viewers of this rich aesthetic resource are few due to the restricted access in the majority of the upper basin but include forest products company, utility, and railroad personnel. Visual quality is therefore high, but visual sensitivity is only moderate due to the viewership.

3.13.2 Middle Basin

The middle basin extends from HHD to the beginning of the Duwamish River. Of the three basins within the Green/Duwamish Basin, the middle basin is the largest in terms of area. Downstream from HHD, the river flows steeply down the 13-mile Green River Gorge. The river emerges from the mouth of this narrow, bedrock gorge at the edge of the Cascade foothills in Flaming Geyser State Park. From here downstream to the City of Auburn, the Green River flows through the broad Green River Valley. Upon entering the valley, the river gradient suddenly declines from steep to moderate. Flood waters at this point spread over a wide floodplain, instead of being tightly confined by the gorge.

At Auburn, the Green River turns north and enters a much larger, flatter valley. The river has been straightened and leveed for most of the middle and lower reaches. As part of the flood control system, much of the river downstream of Auburn is constrained by an extensive system of levees and bank protection.

Agriculture is the major form of human development in the middle basin. As one proceeds down river from HHD toward the Duwamish River, agriculture interspersed with parklands and residential development gives way to a primarily urban landscape, especially below the City of Kent. Rapidly increasing residential development is occurring throughout the basin, especially in the cities of Auburn, Black Diamond, Enumclaw, and Kent.

The visual quality of the middle basin varies with its diverse topography and human development. The upper portion of the middle basin contains more aesthetic resources that are readily accessible to the public than any other portion of the Green/Duwamish Basin. The Green River Gorge, with its associated parks and recreational areas, is the center of this sensitive visual quality area. Visual quality decreases farther downstream as urban development increases.

Viewers in the middle basin include recreationists, residents, agricultural workers, and industrial/commercial workers. Visual quality and sensitivity of the viewers varies from high to low within the basin depending upon the degree of urbanization and viewership.

3.13.3 Lower Basin

The lower basin includes the entire Duwamish River. The region is a wide, flat valley with little variation in topography. Because of flood protection provided by HHD, much of the agricultural land in the lower basin has been replaced by commercial and residential development. The Duwamish River delta has been filled, destroying intertidal habitat. The estuary has been dredged and converted into federal navigation channels. This has led to industrial development, which covers almost all of the shoreline and riparian habitat in the lower basin. The river has also been straightened and leveed for most of the lower reach.

Viewers in the lower basin include travelers on Interstate 5, residents, and industrial and commercial workers. Because of extensive heavy industrial and commercial development of the lower basin, visual quality and sensitivity are low.

3.14 Socioeconomics

3.14.1 Population and Demographics

As the Puget Sound population centers continued to expand through the 1970s, 1980s, and into the 1990s, the Green/Duwamish River Basin has experienced increasing urbanization throughout the middle and lower basins. In 1994, population in the Green/Duwamish Basin was estimated at about 900,000. This included contributions from the following jurisdictions and designated areas: unincorporated King County; the cities of Algona, Auburn, Black Diamond, Burien, Covington, Des Moines, Enumclaw, Federal Way, Kent, Normandy Park, Renton, SeaTac, Seattle, and Tukwila; and the Muckleshoot Reservation (Corps 1995). The City of Seattle and unincorporated King County are the two largest contributors to population in the Green/Duwamish Basin. The cities of Kent, Auburn, and Renton are also major population centers.

Table 3-10 provides data on the numbers of residents in the incorporated cities wholly or partially within the Green/Duwamish Basin in 1990 and 1996. No population estimates are available for 1996 for the cities of Covington or Maple Valley. Except for the City of SeaTac, the populations of the all the incorporated cities in the Green/Duwamish Basin for which there were data grew between 1990 and 1996. The cities of Algona, Black Diamond, Enumclaw, and Kent experienced the greatest growth, with an average annual growth rate of 2 percent or higher.

Data on the gender and ethnic group characteristics of the county and state are shown in Table 3-11. In King County, females outnumber males. Caucasians predominate among the ethnic groups at 84.8 percent of the population in 1990 and 80.0 percent in 1998. The relative percentage of Caucasians within the entire population of the county, as well as for the state, is decreasing. See “Environmental Justice” below for a more in-depth discussion of ethnicity.

3.14.2 Housing

According to the 1990 census, household sizes were fairly uniform throughout the Green/Duwamish Basin and ranged from 2.18 to 3.11 persons per household (Table 3-12). A few incorporated cities toward the periphery of the Green/Duwamish Basin had higher household sizes. Examples of such cities are Covington, Algona, Maple Valley, and Normandy Park, with 3.11, 2.89, 2.75, and 2.64 persons per household, respectively. In general, most of the cities had lower household sizes than the state average of 2.60 persons per household (U.S. Bureau of the Census 1999).

The 1990 median values of owner-occupied dwellings for the incorporated cities within the Green/Duwamish Basin ranged from $72,300 to $196,300 (see Table 3-12). In general, the cities within the Green/Duwamish Basin had higher median values than the state average of $93,400. The cities that had lower median values than the state average were Algona, Auburn, Black Diamond, and Enumclaw (U.S. Bureau of the Census 1999).

According to the 1990 census, the range of vacancy rates for the incorporated cities within the Green/Duwamish Basin ranged from 2.21 percent to 8.48 percent (see Table 3-12). The vacancy rate for the entire King County was 4.87 percent; the state vacancy rate was 7.87 percent (U.S. Bureau of the Census 1999).

Table 3-10. Population Distribution in the Green/Duwamish River Basin

			Average Annual Growth Rate	
City	**1990[a]**	**1996[b]**	**Percent per Year**	**Relative Rate**
Algona	1,694	2,135	4.34	High growth
Auburn	33,650	36,393	1.36	Moderate growth
Black Diamond	1,422	1,967	6.39	High growth
Burien	25,507	26,882	0.90	Low growth
Covington	24,321	ND	ND	ND
Des Moines	17,283	17,811	0.51	Low growth
Enumclaw	7,227	9,500	5.09	High growth
Federal Way	67,535	68,088	0.14	Low growth
Kent	37,960	42,700	2.08	High growth
Maple Valley	1,211	ND	ND	ND
Normandy Park	6,794	6,846	0.13	Low growth
Renton	41,688	45,155	1.39	Moderate growth
SeaTac	22,760	22,723	-0.03	Negative growth
Seattle	516,259	524,704	0.27	Low growth
Tukwila	14,506	14,556	0.06	Low growth
King County	1,507,319	1,598,707	1.01	Moderate growth
Washington State	4,866,692	5,433,068	1.94	Moderate growth

Note: ND = no data available

[a] Census Bureau data as of April 1, 1990

[b] Census Bureau estimate data as of March 12, 1999

Source: U.S. Bureau of the Census 1999

Table 3-11. Gender and Ethnic Group Distribution in the Green/Duwamish River Basin

	Total Population	Male	Female	Caucasian		African American		Native American		Asian and Pacific Islanders		Other	
				Total	%	Total	%	Total	%	Total	%	Total	%
King County													
1990[a]	1,507,319	742,676	764,643	1,278,532	84.8	76,289	5.1	17,305	1.1	118,784	7.9	16,409	1.1
1998[b]	1,665,800	823,053	842,747	1,332,575	80.0	88,993	5.3	18,328	1.1	168,188	10.1	57,716	3.5
Percent Annual Change	1.31	1.35	1.28	0.53		2.08		0.74		5.20		31.47	
Washington State													
1990[a]	4,866,692	2,413,747	2,452,945	4,308,937	88.5	149,801	3.1	81,483	1.7	210,958	4.3	115,513	2.4
1998[b]	5,685,300	2,830,386	2,854,914	4,746,883	83.5	183,681	3.2	92,758	1.6	318,753	5.6	343,225	6.0
Percent Annual Change	2.10	2.16	2.05	1.27		2.83		1.73		6.39		24.64	

[a] Census Bureau data as of April 1, 1990.

[b] Washington State Office of Financial Management estimate data as of March 10, 1999.

Sources: U.S. Bureau of the Census 1999.

Washington State Office of Financial Management 1999.

Table 3-12. Housing Information for King County and the State of Washington as of 1990

Jurisdiction	Population	No. Occupied Housing Units	No. Vacant Housing Units	Vacancy Rate (%)	Mean Household Size	Median Value of Owner Occupied Dwellings ($)
Algona	1,694	587	33	5.32	2.89	72,300
Auburn	33,650	13,357	620	4.44	2.52	91,500
Black Diamond	1,422	541	38	6.56	2.63	83,200
Burien	25,507	10,992	384	3.38	2.32	107,900
Covington	24,321	7,818	334	4.10	3.11	115,200
Des Moines	17,283	7,054	384	5.16	2.45	109,100
Enumclaw	7,227	2,936	95	3.13	2.46	86,100
Federal Way	67,535	25,705	2,382	8.48	2.63	118,800
Kent	37,960	16,246	1,238	7.08	2.34	107,100
Maple Valley	1,211	440	15	3.30	2.75	158,000
Normandy Park	6,794	2,570	58	2.21	2.64	196,300
Renton	41,688	18,219	1,024	5.32	2.29	106,300
SeaTac	22,760	9,611	578	5.67	2.37	93,500
Seattle	516,259	236,702	12,330	4.95	2.18	137,900
Tukwila	14,506	5,639	33	5.58	2.57	93,900
King County	1,507,319	615,792	31,551	4.87	2.45	140,100
Washington State	4,866,692	1,872,431	159,947	7.87	2.60	93,400

Source: U.S. Bureau of the Census 1999

3.14.3 Economy, Employment, and Income

Table 3-13 presents data on the composition of employment and earnings in King County in 1993. King County's large urban/industrial base in the western half of the county biases the data aggregates toward the manufacturing, financial, government, and business services industries. In the rural, eastern parts of the county, agriculture is a relatively more important economic activity.

Table 3-13. Employment and Income for King County (1993)

Industry	Jobs (%)	Earnings (thousands of $)	Per Capita Earnings (thousands of $)
Agriculture, Forestry, Fishing	1.26	526	35.5
Mining, Construction	5.28	2,280	36.7
Manufacturing	13.37	7,028	44.7
Transportation, Communication, Utilities	5.67	2,840	42.5
Wholesale and Retail Trade	22.46	6,532	24.7
Financial and Other Services	39.62	14,731	31.6
Government	12.35	4,619	31.8

Note: Earnings are by place of work and include the proprietors' earnings.

Source: U.S. Bureau of Economic Analysis 1995.

The manufacturing, financial, business and personal services, wholesale/retail trade, and government sectors represent approximately 88 percent of the jobs and earnings of the population of King County. The natural resource utilization (e.g., farming, forestry, fishing, and mining) and infrastructure (e.g., transportation, communication, and utilities) sectors represent only 12 percent of the jobs (Bureau of Economic Analysis 1995).

Table 3-14 presents data on the socioeconomic conditions of King County and the State of Washington. As the data indicate, King County differs from the state averages with respect to levels of income, poverty, and employment. This difference is largely due to the more robust urban/industrial conditions generated by the Seattle metropolitan area and other urbanized areas in the western portion of the county. See "Environmental Justice" below for a more in-depth discussion of this difference.

Table 3-14. Socioeconomic Indicators

Parameter	King County	WA Statewide
Per capita income (1989)	$18,587	$14,923
Population (4/1/89)	1,463,301	4,728,076
No. families below poverty level (1989)	117,064	515,360
Percent families below poverty level (1989)	8.0%	10.9%
Unemployment rate (1991)	4.6%	6.3%
Number unemployed (1991)	40,350	157,370
Public Assistance (average number of persons per month and percent population, fiscal year 1995):		
AFDC – number	68,447	289,199
AFDC – percent	4.24	5.33
General assistance – Number	6,297	20,796
General assistance – Percent	0.39	0.38
Food stamps	5.3%	7.5%
Food stamps – Number	11,052	476,474
Food stamps – Percent	6.88	8.78
Medical assistance – Number	104,225	451,071
Medical assistance – Percent	6.46	8.31

Note: AFDC = Aid to Families with Dependent Children

Sources: U.S. Bureau of the Census 1995
Washington State Office of Financial Management 1999

3.14.4 Environmental Justice

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, requires each federal agency to make the achievement of environmental justice part of its mission. This is to be done through identifying and addressing disproportionately high and adverse human health or environmental effects of agency programs, policies, and activities on minority and low-income populations. The Order further stipulates that the agencies conduct their programs and activities in a manner that does not have the effect of excluding persons from participation in, denying persons the benefits of, or subjecting persons to discrimination because of their race, color, or national origin.

As shown in Table 3-11, minority groups represent approximately than 20 percent of the ethnic makeup of King County in 1998 and less than 20 percent for the state in general. Asian and Pacific Islanders constitute the largest single ethnic minority group in the county. The state, and to a lesser degree the county, has an increasing population that considers themselves of an ethnic background other than "standard" classifications (U.S. Bureau of the Census 1999).

The only Native American land in the Green/Duwamish Basin lies in the southern, central portion of the middle basin and belongs to the Muckleshoot Tribe. Only the northern portion of the Muckleshoot Indian Reservation lies within the Green/Duwamish Basin, though it is near the mainstem of the Green River.

Table 3-14 indicates that King County has a higher level of per capita income ($18,587 in 1989) and lower incidences of unemployment (approximately 4.6 percent in 1991), poverty, and public assistance than the state in general. The greater Seattle metropolitan area provides a vigorous urban/industrial condition that is exhibited in the standard of living in the region (U.S. Bureau of the Census 1995; OFM 1999).

3.15 Public Services and Utilities

3.15.1 Police

The Green/Duwamish River Basin encompasses unincorporated and incorporated portions of King County. Municipal police departments provide protection for the communities within the basin. The ratio of commissioned officers to 1,000 citizens for the entire county is 0.98, compared to a Washington State average of 1.64 (Olympic Pipe Line Company 1998). The police departments in the incorporated communities tend to be staffed with full-time officers and are well funded. Police protection in unincorporated rural areas is provided by the King County Sheriff's Department and the Washington State Patrol.

3.15.2 Fire

County fire protection districts provide fire protection in unincorporated rural areas. Municipal fire departments provide protection for the communities within the Green/Duwamish Basin. Most of the fire protection districts are volunteer districts with limited manpower and equipment. They generally can provide, at most, adequate fire protection to residential, commercial, and farm structures. The municipal fire departments generally include paid full-time fire fighting professionals and larger, more sophisticated fire fighting equipment arsenals.

3.15.3 Hospitals and Emergency Medical Services

Emergency medical services within the Green/Duwamish Basin are provided by primary response ambulance units and area hospitals. In most cases, ambulance units are operated through local fire departments, although there are a few private service providers (e.g., Shepard Ambulance, Inc., and American Medical Response). Those services located in urban areas have paid personnel, whereas the smaller and more rural departments have volunteer staff. Most services provide a basic life support level of care.

Acute-care hospitals are found in many of the cities in the Green/Duwamish Basin and have a varying range of capacity. Acute-care hospitals typically provide emergency medical services that include receiving patients via emergency medical helicopters.

3.15.4 Schools

There are several public schools, colleges, and universities within the Green/Duwamish Basin. In addition, numerous private elementary and secondary schools, colleges, and universities exist within the basin. Many of the private institutions are affiliated with church or religious organizations, and most are located in the more urbanized areas.

3.15.5 Water

Potable water is available to residents living in the Green/Duwamish Basin from a variety of sources including municipal water departments, public utility districts, public water districts, community water associations, individual well systems, and private water companies. Many of these agencies have their own water supply sources and distribution networks. However, several of these agencies have only distribution networks and buy water wholesale from other water supply purveyors. Two such water supply purveyors are Seattle Public Utilities (SPU) and Tacoma Public Utilities. SPU uses water from the Cedar and Tolt River Watersheds. SPU provides water to the City of Seattle in addition to 28 other cities, water districts, and associations (e.g., Tukwila and Renton). Within the City of Seattle itself, the utility provides water to over 325,000 households (SPU 1999). Tacoma Water, a division of Tacoma Public Utilities, draws its water from the Green River at Tacoma Diversion Dam. This is supplemented by seven wells located along the North Fork of the Green River. In addition to providing water to the city of Tacoma and several other cities and communities in Pierce County, Tacoma Water provides water to portions of the Green/Duwamish Basin in South King County. Tacoma Water withdraws on average 72 million gallons of water per day from the Green River (Tacoma Public Utilities 1999).

3.15.6 Stormwater

In urbanized portions of the Green/Duwamish Basin, storm sewer systems or onsite collection and dissipation systems handle stormwater. In less-developed areas, stormwater handling facilities are usually limited to grassy swales along roadways and in some instances retention or detention ponds. Because much of the upper middle basin and the entire upper basin is undeveloped and sparsely populated, no formal stormwater handling facilities exist.

3.15.7 Sewer

In urbanized portions of the Green/Duwamish Basin, underground sanitary sewer systems and sewage treatment facilities handle sewage and wastewater treatment and disposal. In less-developed rural and agricultural areas, sewage treatment and disposal are handled onsite with septic tanks and associated drainfields. Large portions of the upper middle basin and the entire upper basin are undeveloped and unpopulated with no centralized sewage treatment and disposal facilities.

3.15.8 Solid Waste

Solid waste collection services are available to residents living in urbanized areas within the Green/Duwamish Basin from a mix of county, municipal, and private agencies. Many communities contract with private haulers to provide residents with garbage collection and recycling services. Solid waste within the Green/Duwamish Basin is typically hauled to landfills or to transfer stations for railhauling. For example, the City of Seattle operates four transfer stations for consolidation and compaction of solid waste. The solid waste is then transported via railroad to the Columbia Ridge Landfill near Arlington, Oregon.

Much of the less-developed rural and agricultural portion of the Green/Duwamish Basin is outside the coverage area of solid waste collection service providers. Residents of these areas either transport their refuse to established solid waste transfer stations or burn it onsite.

3.15.9 Telecommunications

Telephone and telecommunication services are available to residents within the Green/Duwamish Basin from several service providers. Among these, AT&T Communications, Sprint

Communications, and MCI Telecommunications have the largest customer base and the largest installed network of underground lines and aboveground service facilities.

3.15.10 Energy and Natural Resources

Energy and natural resource services are available from a variety of providers within the Green/Duwamish Basin. Local public utility districts, electrical cooperatives, or larger power companies provide electrical power. Several of these electrical power providers have overhead lines that cross the Green/Duwamish River at various points along its course. Other energy resources available within the basin include fossil fuels. Both Northwest Pipeline and Olympic Pipeline have fossil fuel lines within the vicinity of the mainstem of the Green/Duwamish River. Natural resources that are available through local providers include aggregate gravel, sand, cement, lumber products, and other building materials.

3.16 Cultural and Historic Resources

Cultural resources are the locations of the tangible, physical remains of past human activity. The age of these resources in the region ranges from thousands of years to recent times. The upper limit for classification as “historical” is generally at least 50 years old. The resources themselves may be archaeological sites, buildings, structures, districts, objects, or landscapes. Historic properties are those cultural resources which are eligible for listing on the National Register of Historic Places (NRHP).

The Green/Duwamish River Basin was previously occupied by ancestors of members of the Duwamish and Muckleshoot Tribes. The Tribes have an interest in preserving traditional values and cultural resources. A traditional cultural property is one that is eligible for inclusion in the NRHP because of its association with the cultural practices or beliefs of a living community. These properties are rooted in the community’s history and important in maintaining the community’s cultural identity. Particularly important are sacred landforms, ceremonial sites, rock art, cairns, certain animal and plant resources, and locations prominent in mythology and tribal history. Also of importance are cemeteries and isolated interments. Any human remain discovered may be subject to provisions of the Native American Graves Protection and Repatriation Act. State laws that address archaeological sites and Native American burials include the Archaeological Sites and Resources Act (RCW 27.53) and the Indian Graves and Records Act (RCW 27.44).

The following assessment relies on information about recorded archaeological and historical sites on file with the Washington Office of Archaeology and Historic Preservation and on a review of ethnographic sources. Several studies were reviewed that compiled place names and descriptions of places important to the native inhabitants of the Green/Duwamish Basin. This study does not include information on all traditional cultural locations that may be of importance to native people in the Green/Duwamish Basin.

The distribution of historic properties within the Green/Duwamish Basin is the result of past environments and the prehistoric and historic use of the region’s resources. The geological setting, hydrology, fisheries, vegetation, and wildlife have been described in earlier sections. Changes in climate and landscape over time have had a major influence on where and how native people lived in the Green/Duwamish Basin for the last 12,000 years.

3.16.1 Prehistory

3.16.1.1 Lower and Middle Basin

The earliest regional evidence of human occupation consists of a small number of fluted Clovis or Clovis-like projectile points characteristic of the period between 12,000-11,000 Before Present (B.P.), and Olcott sites, thought to represent a period of occupation prior to development of marine-oriented cultures. Olcott assemblages are characterized by tools manufactured from locally obtained cobbles, including large leaf-shaped and stemmed points, and cobble and flake tools. After about 5,000 B.P., larger populations organized in more complex ways exploited a wide range of locally available resources, including shellfish, salmon, small mammals, berries, roots, and bulbs. Shell middens are numerous on saltwater shorelines; the apparent lack of earlier shell midden sites is due to inundation of earlier shoreline sites by rising sea levels, which did not attain near-modern levels until c. 5,000 B.P. Emphasis on salmon exploitation grew over time as large-scale fishing, processing, and storage technologies were developed.

Full-scale development of marine-oriented cultures on the coast and inland hunting, gathering, and riverine fishing traditions as represented in the ethnographic record are apparent after c. 2,500 B.P. A wide variety of ground and chipped stone and bone artifacts made of both local and imported materials occurs, representing complex and diversified technologies for fishing and sea mammal hunting, processing, and storage.

3.16.1.2 Upper Basin

Until relatively recently, prehistoric use of the Cascades was assumed to have been limited in extent and duration, covering perhaps the last 2,000 years. Archaeological investigations conducted over the past two decades have demonstrated that seasonal use of the central and southern Washington Cascades by both Puget Lowland and Columbia Plateau groups has been widespread, however, and has occurred over thousands of years.

The historic period (post-250 B.P.) is marked by dramatic changes in native populations and community composition resulting from the introduction of epidemic diseases and Euroamerican goods and settlement. By the time most ethnographies were written in the late 19th and early 20th centuries, these changes had already significantly altered native cultures. The transmission of smallpox and other epidemic diseases, which infected some groups before direct contact, resulted in a drastic decrease in the American Indian population in the first century of contact. Acquisition of horses also changed the groups who obtained them, allowing them to greatly increase mobility and carry heavier loads, which apparently led to significantly increased use of the mountains as well as expanded trade networks.

3.16.2 Ethnography and Ethnohistory

As mentioned earlier, the ethnohistoric and ethnographic record of Native American groups in the Northwest documents societies that were significantly altered by contact with Euroamericans. Dramatic changes in native populations, community composition, and cultural traditions occurred in the late 18th and early to middle 19th centuries, before most ethnohistoric and ethnographic records were made. The introduction and transmission of smallpox and other epidemic diseases, which infected some Native American groups before direct contact with Euroamericans, resulted in a minimum estimated loss of over two-thirds of the Native American population on the southern Northwest coast in the first century after contact. The introduction of Euroamerican guns, iron, blankets, foods, and livestock, which began with the fur trade, also altered native economies.

3.16.2.1 Lower and Middle Basin

The Puget Lowlands portion of the project area is in the ethnographic territory of the Duwamish and groups that later became the Muckleshoot Tribe. The Duwamish territory included Elliott Bay and the valleys of the Duwamish, Black, and Cedar Rivers. The term Duwamish originally applied to the inhabitants of nine villages, including four on the south end of Lake Washington and the Black River, and one on the Cedar River at Maple Valley. The contemporary

Muckleshoot Tribe is an amalgam of bands that occupied the Green and White River drainages from the rivers' confluence in present-day Auburn to their headwaters in the Cascades: the Buklshuhls, Skopahmishes or Green River Indians, and the Smulkamishes from the Enumclaw vicinity. Eight Skopamish villages were distributed along the Green River from Auburn to Flaming Geyser State Park. Villages were also farther up the White River at Boise Creek near Enumclaw, and on the Green River at Newaukum and Burns Creeks near Flaming Geyser State Park. Camps were located near Kanasket and at the Green River Hot Springs below Lester. As was typical of the Puget Sound Salish, each of these groups and villages was politically autonomous although bound to others in the basin by kinship, language, and social and economic interactions of various kinds.

Salmon was the most important element of the subsistence economy, but a wide variety of fish, shellfish, roots, bulbs and berries, and mammals was exploited and preserved for later use or trade. Fish weirs were constructed at various places in the rivers to create a barrier, and the fish speared or netted there as they returned to spawning streams. One large fishing camp was located at present-day Kanasket; from there, smaller groups traveled to fishing spots higher in the basin.

Marshy shores and prairies were utilized for resources including wapato and camas. Meadows and prairies also provided forage for large and small game. After the establishment of Fort Nisqually in 1833, the Indians regularly traded with the Hudson's Bay Company (HBC). Potatoes obtained from the HBC were cultivated by the Duwamish in the Black River Valley (Lane 1975:6).

The Duwamish, who signed the Point Elliott Treaty in 1855, were assigned to the Port Madison Reservation on the Kitsap Peninsula, but most had returned to the Seattle area by 1857. They were subsequently assigned to the Muckleshoot Reservation near present-day Auburn, which was closer to their traditional territory, although many continued to live in the Seattle and Renton area. The Muckleshoot Reservation is an indirect result of the Medicine Creek Treaty of 1854 which scheduled tribes from the Green and White Rivers to move to the Nisqually Reservation or to a more suitable place. In 1856 the Muckleshoot Reservation was established as that "more suitable place" and in 1874 it was approved by executive order.

Nearly 600 named ethnographic locations representing villages, camps, resource locations, features of the landscape, and mythological representations were recorded in the first decades of the 20th century in King County, primarily in the lower and middle basin. Many of these sites have been destroyed by development in the lower basin, while archaeological sites associated with others have been discovered and preserved. Native American trails, including portions of the trail from Elliott Bay over Snoqualmie Pass, were often used by early settlers and built into wagon roads and later into highways.

3.16.2.2 Upper Basin

Muckleshoot tribal members have identified the upper reaches of the Green River as a place where they met and traded with the Yakama. The main route used by the Muckleshoot Tribe to visit with the Yakama was the trail over Naches Pass via the White and Greenwater River Valleys, which was also used extensively by the Yakama to travel to western Washington. The

Green River groups also regularly interacted with the Klickitat, who lived to the south in the Mount St. Helens-Mount Adams region.

Upland areas continued to be used for fishing and hunting after the reservations were established and well into the 20th century. Muckleshoot people continued to travel to Huckleberry Mountain well into the 1920s, although access was from the Greenwater side of the ridge after the City of Tacoma Watershed was created in 1912. The hunting camp near Green River Hot Springs was used historically as a base for hunters and to smoke-dry deer meat.

3.16.3 History

3.16.3.1 Lower and Middle Basin

Fur trading expeditions of the British first brought frontiersmen and traders through the Duwamish/Green River Valley as the HBC expanded its network of posts in the Columbia region. Euroamerican settlement of the lower basin area began in the late 1840s and 1850s. By 1853, donation land claims had been filed in Seattle, along the Duwamish, Green, and White Rivers. The Puget Sound Indian Wars of 1855-56, which started in the White River Valley and extended north to Seattle, temporarily interrupted white settlement. In the 1860s, river boats went as far upstream as Kent and small steamboats plied the river and, in the 1870s, competed with narrow-gauge railroad spur lines. In the 1880s, the transcontinental railroad was completed over Stampede Pass. Completion of this transportation link opened new markets for goods and ensured survival of permanent communities with economies based on agriculture, logging, and mining.

The earliest major commercial endeavor in south and east King County was coal mining, which was underway in Newcastle east of Lake Washington by 1870 and in Renton by 1874. Coal was transported to Seattle overland and across Lake Washington or overland and by barge down the Black and Duwamish Rivers to Elliott Bay. The first large-scale commercially grown crop in the Puget Sound area was hops, which were exported to English and eastern U.S. grain markets. Hops were widely cultivated in the lower White River, Squak, and Snoqualmie Valleys, and were lucrative for farmers with large land holdings. The world's largest hop farm at one time was located near North Bend (Seattle Times, April, 1995). In the late 1950s, plans were begun for the construction of HHD and a high speed road system including the Valley Freeway and major interstates. A cycle of annexation and speculation by communities and corporations began in anticipation of future urban use. Before 1957, most land in the valley was in individual farm ownership. After that time large plots were bought by corporations and railroads in anticipation of conversion. In 1961, physical change began with the construction of the first industrial park. In the mid-1960s, Boeing completed construction of its Kent Aerospace Center. By 1967, Southcenter was built and the I-5 and I-405 freeways were completed (Jones and Jones 1979). In the early 1990s, Boeing began the process of replacing Longacres Park Racetrack with offices and training facilities.

3.16.3.2 Upper Basin

Most early settlers in the upper Green River Watershed were employed in logging and building the Northern Pacific Railroad over Stampede Pass. Homesteads were built along the river and lower reaches of larger tributaries such as Say Creek, between the towns of Humphrey and Lester. Japanese laborers made up approximately 25 percent of the work force in the mills during the early days of operation, and like the Chinese workers, they usually lived in segregated housing within the camps (Carter 1978; Hollenbeck 1983; Lewarch et al. 1996).

The Northern Pacific sold some of its land grant sections in the valley to timber companies after the line was completed in 1887. Commercial logging began shortly afterward, and logging railroads were built up tributary creeks into higher elevation areas. One of the largest operations in the area was that of the Morgan Logging Company, which logged slopes north of the Green River, up the Say Creek drainage, and milled the lumber near the mouth of the creek at Nagrom. Camps were also located at Lester, Humphrey, Baldi, and Mayfield. During the 1920s, many of the smaller logging operations were bought out in an industry-wide consolidation. Most of the remaining operations closed down during the Depression (Carter 1978; Hedlund et al. 1978:85-6; Lewarch et al. 1996:20).

Concurrent with the creation of the USFS in 1905 was transfer of the old Forest Reserves from the Department of the Interior to the Department of Agriculture. Much of the early work of the USFS was related to the creation and enforcement of grazing regulations, fire suppression, and timber sales. In the 1930s, recreation benefited from creation of the Civilian Conservation Corps (CCC), which improved and constructed facilities including water systems, roads, lookouts, ranger and guard stations, trails, trail shelters, ski areas, and scenic viewpoints. They were also involved in fire fighting and forestry. The CCC constructed a USFS road through the upper Green River Valley and had a camp just east of Lester.

3.16.4 Archaeology

3.16.4.1 Lower and Middle Basin

Excavations to satisfy mitigation requirements have taken place at several sites in and near the Green/Duwamish Basin, including the Duwamish No. 1 site on the lower Duwamish River, sites on the Black River in Renton, and recently West Point, Seattle, and Allentown. These sites are all associated with the marine shoreline or lower river courses. All except West Point, which has radiocarbon dates ranging from 4,300 to 200 B.P., date between c. 2,000 and 100 B.P. Data recovery excavations were conducted at two sites on the Black River: 45-KI-51 (Sbabadid), a Duwamish village site occupied c. 1790 to 1820, and 45-KI-59 (Tualdad Altu), a summer fishing camp used c. 1,600 years ago. Data recovery was also recently completed at a site on the Duwamish Waterway near Allentown less than two miles northwest of the project site, 45-KI-431.

Other sites found as a result of planned construction include: 45-KI-6, a shell midden observed 10 feet below the ground surface in a bank exposure southwest of the existing course of the river and in the path of a relocation channel (Dalan et al. 1981); and 45-KI-439 near the Black River found prior to construction of a Fred Meyer store (Lewarch 1994). Site 45-KI-41 is the location of a cedar dugout canoe found eroding from the bank of the Green River one meter below the ground surface. Only one site, 45-KI-267 on Surge Tank Hill above the Green and Black River confluence, was not buried. Surge Tank Hill is an older, higher, rocky land form surrounded by post-5,700-year-old fine-grained deltaic sediments.

3.16.4.2 Upper Basin

Excavations at higher elevations in the Cascades have increased, and results indicate that seasonal use of the mountains occurred over thousands of years and was much more extensive than was understood just a decade ago. The following tested or excavated prehistoric archaeological sites in the upper basin are along or near the Divide Ridge: three lithic scatters on Huckleberry Mountain (45-KI-53; 45-KI-54; 45-KI-435); Government Meadows (45-KI-36); Fitch (45-KI-34); Meadow Creek (45-KI-37); and the Naches Lithic Scatter (FS# 06-05-07-31). Most are interpreted as hunting and berrying camps, likely associated with travel over Naches Pass.

No prehistoric archaeological sites have been identified in the upper Green River Valley, except those found as a result of survey of the HHD reservoir pool area. Here, 13 lithic scatters were found on terraces of the river during a drawdown. Projectile point types suggest the area was occupied between about 3,500 and 8,000 B.P.

3.16.5 Archaeological and Historical Record

A total of 166 historic and prehistoric properties have been recorded in the Green/Duwamish Basin study area. Of this number, 89 are in the lower basin, 32 are in the middle, and the remainder (45) are in the upper basin. Most of the properties are historic (109) and most are located less than a quarter mile from Puget Sound, the Green River, or one of its named tributaries.

In the upper basin, management of the Mt. Baker-Snoqualmie National Forest and HHD by federal agencies has resulted in project-related cultural resources studies as stipulated by the National Historic Preservation Act. Most of the sites in this basin were recorded by the USFS, or during work sponsored by the USFS or the Corps.

Many of these properties were evaluated using criteria for eligibility for the NRHP, with 33 of the properties listed on the Register and 14 recommended as eligible. All but one of the National Register listed properties is an historic building or structure. A single prehistoric site, 45-KI-23, the Duwamish No. 1 site, is listed. Properties recommended as eligible are all archaeological sites. Although more properties may have been evaluated and recommended as eligible, extensive report review to verify eligibility was not undertaken, and the Office of Archaeology and Historic Preservation maintains no listing for this attribute.

Two other historic structures are National Historic Landmarks and 25 other buildings, structures, or locations are included in the Washington Historic Register.

3.16.5.1 Lower Basin

Most sites in the lower basin, whether historic or prehistoric, are within a quarter mile of Puget Sound. Most of the sites are buildings that represent the history of Seattle. Eleven sunken vessels recorded in Elliott Bay (45-KI-406 through 45-KI-417) are among the recorded sites. Prehistoric sites are primarily middens on Puget Sound (nine sites), the Duwamish River (four sites), or the Black River (four sites). One site is a petroglyph carved into a boulder and the last is a record of artifacts collected by construction workers.

3.16.5.2 Middle Basin

The 32 sites of the middle basin are associated primarily with the Green River. Historic sites include a variety of agricultural and industrial locations representative of settlement, mining, and transportation. The prehistoric sites are lithic scatters, petroglyphs, and in one case, a shell midden. Two sites have both historic and prehistoric components. Five of the 14 prehistoric sites are located more than a quarter mile from the Green River or a named tributary.

3.16.5.3 Upper Basin

Most of the recorded sites in the upper basin are associated with small tributaries of the Green River. Because many of them are trails entering the valley down steep side slopes, there is little direct correlation of site location and watercourse. The sites recorded at Howard Hanson Reservoir, however, are directly related to the river. These locations on terraces above the river probably represent seasonal hunting, fishing, and gathering. Historic sites are related to logging and include mill sites, logging camps, and town sites.